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Research and Technology

1983
Annual Report of the
Marshall Space Flight Center

25th Anniversary
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INTRODUCTION

The FY 1983 report reflects a continuation of MSFC's many R&T accomplishments. The activities reported are a measure of the dedication and capabilities of MSFC's technical personnel. Of particular interest and pride are the increasing number of accomplishments in the SSME and Large Space Systems Technology Programs. At the same time, our research programs in materials processing in space, the atmospheric sciences, and the space sciences continue to yield valuable knowledge about the universe. The Center is pleased to acknowledge a growing awareness of its R&T programs, as evidenced by the increasing number of requests for this report by members of the aerospace industry, academic colleagues, and the public at large.

This report is presented in three sections--Advanced Studies, Research, and Technology. Although the accomplishments for FY-1983 are described in the sections on Research Programs and Technology Programs, the introductory section on Advanced Programs provides the background for the requirements under which our R&T programs are conducted. Thus, while the R&T activities are valuable in their own right, no activity is begun unless it responds to an existing or anticipated program need. The Research Programs section includes our accomplishments in the atmospheric sciences, space sciences and materials processing in space. Although the materials processing in space activities are generally perceived to be highly focused towards the understanding of the influence of gravitational effects on materials properties, it is generally recognized that any advances in this discipline may have a profound impact upon man's understanding of the universe in general. Hence, it is entirely appropriate that these three research areas be grouped together.

The section on technology programs contains reports from space power, materials, processes and space structures. Although there is a tendency to consider technology development to be less rigorous than activities in the research programs, these programs require the application of the same scientific and engineering methodologies as do the research programs.

The names, organizational symbols and telephone numbers of the contributors to the report as well as lists of pulbications generated during the reporting period are included at the end of the respective topics. If more information about any of these activities is desired, the individuals identified herein may be contacted directly.

SPACE STATION

NASA spent the last year and a half initiating a very careful definition process for a Space Station so that an informed decision can be made on whether or not the Space Station should be the next major step for the U.S. Space Program. The planning mechanism is a NASA Space Station Task Force established in May 1982 by the NASA Administrator. The activity is a NASA-wide effort involving all NASA Centers and Headquarters reporting to the NASA Associate Deputy Administrator. The Task Force provides focus and direction for planning, concentrating on mission requirements, architectural options, trade studies, advanced development, concept development, systems engineering and program planning. MSFC has been actively involved in all these areas during the past year.

Primary activities were system and subsystem trade studies to assist the Task Force in defining an overall Space Station architecture that can be conceptualized as a cluster in space. The cluster includes both manned and unmanned elements. The manned base is made up of a habitat module, a resource module providing electrical power and thermal functions, an operations module in which to conduct experiments and other development activities, and a docking hub to be used for receiving transportation elements, supplies and inhabitants. The unmanned elements perform various functions in the infrastructure, such as science and Earth observations, or materials processing. The manned and unmanned elements are complemented by other functions and capabilities, such as the ability to perform extravehicular activity and to deploy and retrieve free-flyers with the use of an Orbital Maneuvering Vehicle (OMV). The Space Station may be used to support space-based Orbit Transfer Vehicles (OTV), used to place payloads in high energy orbits, including geosynchronous placement and retrieval and planetary injection. An example of this Space Station architecture is shown in Figure 1.

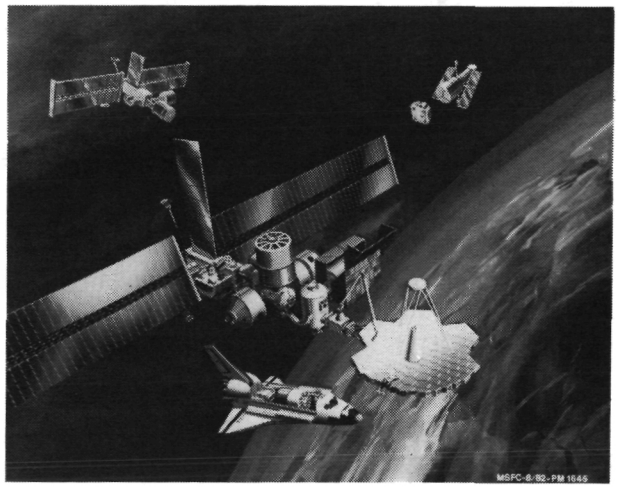

Figure 1. Space Station.

In October 1982, four studies were initiated by MSFC to identify and analyze the use of an early Space Station in developing operational capabilities for satellite servicing, servicing OTV and construction/assembly of large space structures. These contracted studies were extended in mid-1983 for a period of 18 months to provide in-depth analysis and trades on related mission scenarios.

MSFC also initiated several advanced development proposals concerning electrical power, on-board propulsion, guidance and control, space operations mechanisms, thermal control, and data management. Other proposals in the areas of fluids management, structures, communications, and human capabilities will be submitted in late 1983. The advanced development plans and/or proposals outline the methods and concepts for developing the Space Station technology and include the focused technology, prototype development, test beds and related flight experiments.

Advanced development activities in several related areas were continued through operation of existing breadboards such as electrical power, guidance and control, docking and berthing simulation, thermal control, and neutral buoyancy tests.

Control Moment Gyroscope (CMG) life tests of bearing and slip rings were continued to support CMG design modification. The CMG Spin Bearing Life Test has now successfully completed 13,000 hours of testing and the CMG Slip Ring Life Test successfully accumulated over 12,000 hours. Outgassing tests continue to indicate that the seals which were added to prevent excessive lubricant outgassing are fully effective. A math model for a CMG hybrid simulation system was developed and checked out and will be used to simulate Space Station motion and inertial properties.

Docking mechanisms were evaluated using the Center's six degree-of-freedom motion simulator to evaluate prototype docking mechanism hardware for the OMV and Space Station. The RMS end effector is a candidate for this application, and preparation for docking dynamic analysis is near completion. This activity is to develop video signal processing techniques which can operate in real time or near real time so that meaningful tasks such as orbital inspection, docking, servicing, or assembly may be possible. Those techniques will be implemented with a computer compatible TV and an array processor, and evaluated using MSFC orbital docking simulators. Methods being developed use two-dimensional Fast Fourier Transforms and artificial intelligence techniques for syntactic pattern analysis.

MSFC also continued advanced development activities in related areas. The Electrical Power System (EPS) testing was continued to determine the performance of high voltage electrical power systems using programmable power processors and the operation and charge control of high voltage NiCd batteries. Two 88-cell, 55-AH batteries are being tested to investigate charge control techniques in efforts to achieve optimum performance under low Earth orbit conditions and to investigate the effects of high rate pulse discharge demands on the batteries. One battery has accumulated 10,780 orbital cycles (5000 this year), while the second has accumulated 4800 cycles.

Neutral buoyancy tests were conducted to demonstrate space platform orbital maintenance and growth operations. This was a joint effort with TRW and MDAC and supported by MSFC facilities and personnel. The TRW test addressed the removal and replacement of a large modular Orbital Replaceable Unit (ORU) mounted on a space platform. The large modular ORU was 58" x 47"

x 30" and weighed approximately 1,500 pounds. An evaluation was made of the ORU transfer, manipulation, mechanical mounting fasteners, and fluid and electrical connectors mating/demating. The MDAC test addressed: (1) the EVA appendage deployment by means of a hand crank to override a failed automatic mechanism, (2) EVA ORU exchange and translation with various size ORU ORU's, (3) connector tools and adjustable foot restraint evaluation, (4) contingency operations for manual jettison of appendages and fluid transfer simulation, (5) structural modifications to strengthen the payload port of an unmanned space platform to support the attachment of a manned module, and (6) adding a growth module on-orbit by EVA operations to an existing operational space platform. The concepts tested are applicable to the genre of satellites, space platforms, and Space Stations which will be placed in orbit and revisited by the ground-to-orbit and orbit-to-orbit space vehicles. Figures 2 and 3 depict some of these test activities.

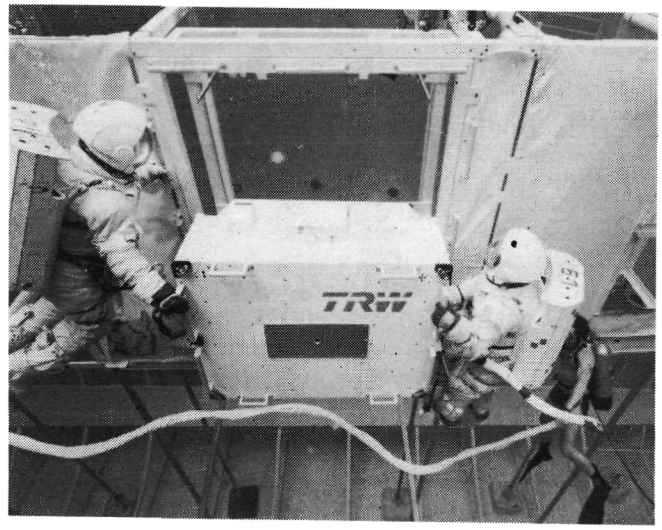

Figure 2. Large Modular ORU Changeout.

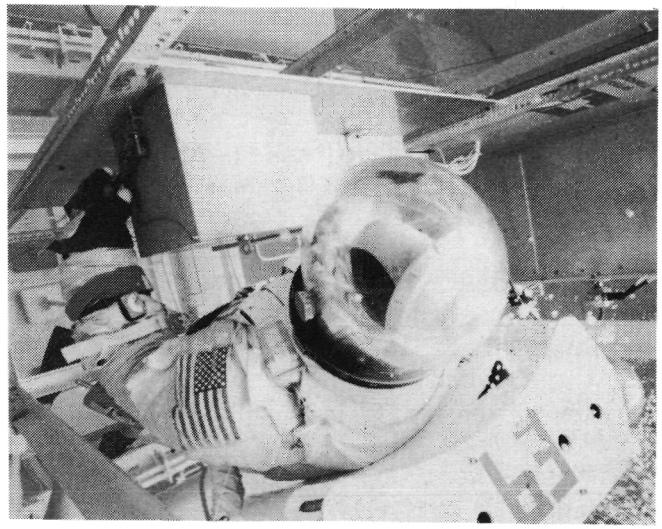

Figure 3. Small Subsystem Component Changeout.

MSFC conducted thermal vacuum tests on the TRW-developed thermal/structural test article designed to evaluate the performance of large replacement equipment carriers. The test program consisted of a Thermal Vacuum Test (TVT) followed by a vibration test and then a second TVT. The first TVT established a baseline for thermal characteristics of the test article. The vibration test served to simulate the dynamic conditions of a Shuttle ascent to orbit. The second TVT reverified that thermal performance did not degrade due to launch loads. Several component-to-cold-plate interface materials were evaluated during the test program. These included RTV, a thermal grease, and a semiconductor foil. The results showed that pre-vibration and post-vibration thermal performance were similar for all interface materials. (C. Gregg/PM01/205-453-0541)

SPACE STATION TECHNOLOGY

Current planning for the early Space Station shows the time table for initial operational capability to be the beginning of the 1990's. This schedule allows adequate time for planning and conducting a technology program to provide an optimum design and lower life-cycle cost, and to improve evolutionary growth potential. A system technology study has been conducted this past year with the Boeing Company to determine those Space Station technologies having the highest potential for providing the above benefits. The approach used past technology planning, particularly the results from the NASA Space Station Technology Steering Committee activity, enhanced these with industry expertise, and quantified the benefits of technologies having the highest potential. A plan for resolving each selected technology was the final product of the study. This plan described the technology rationale, test requirements, facility needs, schedules and costs. Technologies identified as having the highest benefits and needs and thereby having the highest priority for resolution in the data management automation and thermal control disciplines were, respectively, local area network architecture development, hierarchal controller development for subsystem management, and thermal storage system for single and two-phase fluid transport. Specific results from this system technology study are provided in the following document: Advanced Platform Systems Technology Study, Volumes I, II, III and IV, Boeing Aerospace Company, D180-27487, April 1983. (R. Nixon/PD21/205-453-4165)

SPACE APPLICATIONS OF AUTOMATION, ROBOTICS, AND MACHINE INTELLIGENCE SYSTEMS (ARAMIS) PHASE II - TELEPRESENCE

This Phase II contract immediately followed the completion of the ARAMIS Phase I research. It covers the telepresence technology base development and provides overviews of those capabilities that are now available, and those that will be required to support a NASA telepresence effort. A technology development program leading to the development of an operational telepresence system by 1992 is presented. An example from the developmental program leading to an operational telepresence servicer is presented in Figure 4. Presently, this available knowledge is being used in

the area of satellite servicing studies (OMV) and in Space Station operations planning. (G. von Tiesenhausen/PS01/205-453-2789)

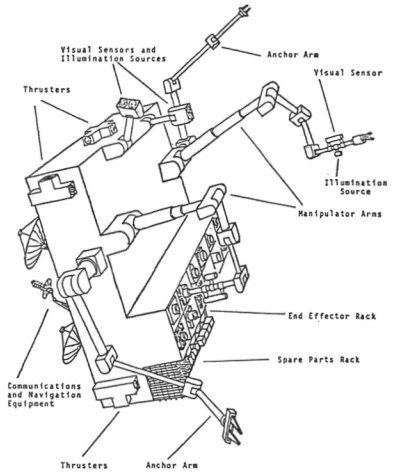

Figure 4. Conceptual Telepresence Servicer Unit.

AFT CARGO CARRIER

The Aft Cargo Carrier (ACC) is being studied as a potential improvement to the Space Shuttle launch system. The ACC attaches to the rear of the Shuttle's External Tank, and can carry payloads up to 25 feet in diameter and 20 feet long.

A variety of payload applications are being studied, such as commercial GEO, future NASA special payloads (orbital transfer vehicle, etc.), and large special purpose DOD payloads. (J. Hughes/PS03/205-453-2813)

PROPELLANT SCAVENGING

Study activities have begun to investigate the techniques and technology involved in scavenging propellants that remain in the Shuttle External Tank (ET) and feed lines at the completion of the Shuttle mission. The excess/residual propellants can be withdrawn from the ET and propellant lines and placed in containers in the aft cargo carrier for transfer to the Space Station via the OMV for use in the space-based OTV, Space Station, etc.

Technologies required to transfer cryogenic propellants from the ET into the transfer tanks and from the transfer tanks into the orbital holding/storage tanks under zero gravity will be identified. (M. Page/PS03/205-453-2817)

MATERIALS PROCESSING IN SPACE (MPS) POWER REQUIREMENTS

The previous analyses of the cost of performing research in space have shown that longer stay-time, together with more power to run experiments, can dramatically reduce the unit cost of experimentation. Furthermore, ground-based research and flight experiments to date have shown that the

significant number of samples that must be processed in order to isolate, characterize and develop MPS research and the power requirements for processing apparatus are typically higher than for other kinds of space activity. It is already apparent that the electrical power and energy resources of the Shuttle-Spacelab system will become a serious limiting factor to the MPS program at the levels of activity that are expected in the mid-1990's. Thus, the Space Station capability and MPS needs can be matched. In operational terms, the Space Station provides the opportunity to extend the orbital stay-time while supplying a higher power level to experiments.

MPS program planning has determined that a useful mode of operation will be to attach MPS experimental module to the Space Station, to be operated between visits from the Shuttle. This operational mode will require a module to support MPS experiments and subsystems to operate them. This assembly of hardware for this purpose is expected to require about 20 kW per module.

Initial operation will begin with one module and is expected to grow to a maximum of three. Power systems to generate these amounts of power, together with subsystem components to manage power switching, etc., will be needed. (W. Vardaman/PS05/205-453-2788)

GEOSTATIONARY PLATFORM

Recent conceptual studies have shown that a single Shuttle-launched experimental platform is needed in the early 1990's to enable operational geostationary platforms to follow. This platform would demonstrate an integrated system of communications and platform technologies. The baseline platform included 10- and 15-meter-diameter antennas of different construction concepts, deployable truss structures, a good mix of science and applications payloads, both C-band and UHF technology demonstrations, thermally stable structures, docking and servicing capability, high-frequency high-voltage AC power, high efficiency power system components, experimental active stabilization, experimental North-South station keeping and other advanced technologies. This platform weighs 12,000 pounds and provides 8 kW of power.

An alternative version for a second-generation operational direct broadcast mission was also defined. And a 4-platform operational system utilizing GHz for time zone coverage was analyzed. This system had on each platform 40 channels using two 2.9 meter reflectors, several 200 watt TWTA's, a mass of 5250 kg and a 30 kW power source. Possibilities for a direct broadcast Experimental Geostationary Platform were studied. It was determined that the Baseline Experimental Geostationary Platform could be easily modified to accommodate a direct broadcast mission.

Technologies that would be demonstrated by this platform include deployable structures and structural mechanisms; active stabilization of large space structures; a high efficiency AC power system; LEO-to-GEO transfer of deployed structures; automated unmanned servicing at GEO; platform inter-module docking; an integrated attitude control system for docked platform modules; multi-beam antennas; scanning-beam antennas; accurate beam pointing; inter-platform links; onboard communication switching and processing; a platform communications controller/processor; link

performance enhancement techniques; high effective isotropic radiated power and small Earth station antenna; dual polarization Ka Band; and use of high-power, long-life spacecraft traveling wave tube amplifiers. New technologies this platform would demonstrate, in addition to those listed previously, would be the use of high power TWTA's in a geostationary application, a larger power system and a high capacity heat dissipation system in space. (R. Durrett/PS04/205-453-5747)

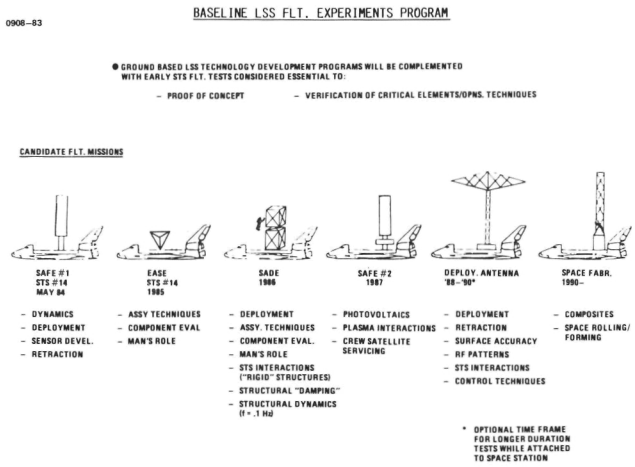

Figure 5. Baseline Large Space Systems Flight Program.

LARGE SPACE SYSTEMS (LSS)

A number of projected space missions for the period 1988 to 1995 (including Space Station, VLBI and Geostationary Platform) involve the use of large space structures. To ensure that the LSS hardware and operations technology are available to meet the needs of future mission needs, MSFC has implemented an LSS technology development program comprised of both ground and flight experiments. The ground based program includes a broad range of future large systems technology requirements supported by basic R&T activities, such as environmental effects on materials, thermal control and space vehicle dynamics. Ground tests of selected structural elements (deployable masts/trusses) and assembly simulations in MSFC's neutral buoyancy facility have been underway for some time, and will establish the foundation needed to proceed with the flight test program. The flight test program, as outlined in Figure 5, consists of six basic missions of increasing complexity with time, with early emphasis on assembly and deployment techniques and LSS dynamics. Mission needs for space fabrication technology are now perceived to be well downstream (mid-90's or beyond); therefore MSFC's activities and proposed flight experiments in this area have been deferred. Selected elements of the ground and flight programs are described below. (D. Cramblit/ J. Harrison/PS04/205-453-2795)

Structural Assembly Demonstration Experiment (SADE)

The purposes of SADE are to extend the flight experiment activity begun by EASE to demonstrate that the Shuttle has the capability to build a large aluminum structure in space, to measure the extent to which MSFC's Neutral Buoyancy Simulator (NBS) can accurately simulate assembly activities in space and to validate the truss design and the assembly procedures. The truss will be assembled in the Shuttle bay over a period of several hours using astronaut EVA assistance, tools and other Shuttle resources (i.e., RMS) as well. Tests have been carried out in the NBS to simulate space construction of the truss and to obtain data for comparison with flight data for later use in correlation studies. An in-house systems study has been completed that narrowed the final flight configurations to two, defined a prospective flight data system, and outlined a Shuttle-extended truss control experiment. A sketch of the current concept is shown in Figure 6. (J. Harrison/PS04/205-453-2795)

Figure 6. Structural Assembly Demonstration Experiment (SADE).

Large Deployable Astromast

A 50-foot length, 30-inch diameter, deployable boom is being built by Astro Research Corporation for ground test in 1984 at MSFC. The boom is a lattice-type structure made up of battens that run in a horizontal and diagonal direction, with respect to the axis of the boom and longerons that run the full length of the boom and coil to permit the mast to fold. The crosssection of the boom is triangular. A motor-driven winch and lanyard system will be used to deploy and retract the mast, which is made of S-glass epoxy.

The purpose of this program is to build and ground-test a large deployable boom that will be a prototype for booms to be used on future space systems.

An intermediate length (20 feet) deployable boom, of the same design as the 50-foot length, was built in 1982 by Astro Research and tested in 1983 at MSFC. A photograph of it undergoing a test is shown in Figure 7. (J. Harrison/PS04/205-453-2795)

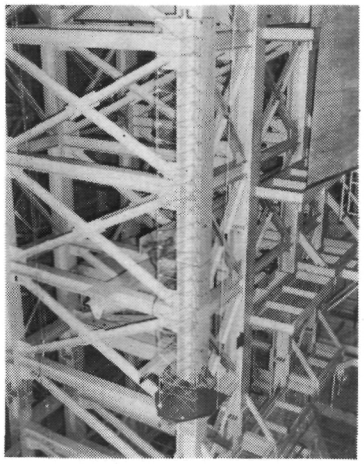

Figure 7. Large Deployable Astromast Undergoing Vibration Tests.

Experimental Assembly of Structures in EVA (EASE)

EASE is the EVA construction in space of a simple tetrahedron-shaped structure using six aluminum tubes 12 feet long. The tetrahedron will be assembled and disassembled repeatedly in the Shuttle bay on an MPESS pallet as many times as possible during a single EVA using two EVA crewmen. The Shuttle RMS will not be used and only video and photographic data will be taken. A sketch of EASE is shown in Figure 8.

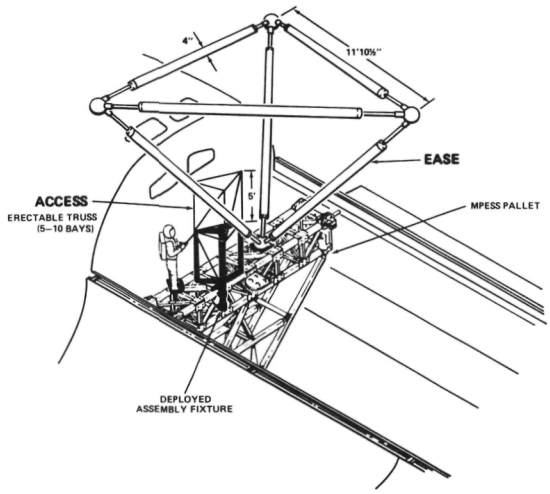

Figure 8. Experimental Assembly of Structures in EVA.

The purposes of EASE are to demonstrate the feasibility of space construction and the value of the Neutral Buoyancy Simulator (NBS) for simulating space assembly.

A preliminary program plan has been prepared for EASE and a contract has begun with MIT to fabricate the flight hardware. (J. Harrison/PS04/205-453-2795)

Space Deployable Truss

A deployable truss, designed to the requirements of an early space platform/Space Station, was fabricated and delivered to MSFC. Automatic deployment under simulated zero-g conditions was performed using air bearings and a flat floor. The test article, shown in Figure 9, consists of the deployable truss deployment mechanism, two utility trays and a representative complement of utilities (power, data and fiber optic cables). Hardpoints are incorporated into the structure to accommodate up to four payloads, each having a mass of 8,000 lbm. The deployed truss size is 4.5 feet high, 4.5 feet wide and 45 feet long. Stowed dimensions are 4.5 feet high, 9 feet wide and 5 feet long. Deployment is achieved by taking up two cables routed through the diagonal members on each side of the truss. Deployment and structural tests were successful. Other versions of deployable trusses, designed to reduce the stowed volume, are under development. (E. Engler/ EP13/205-453-3958)

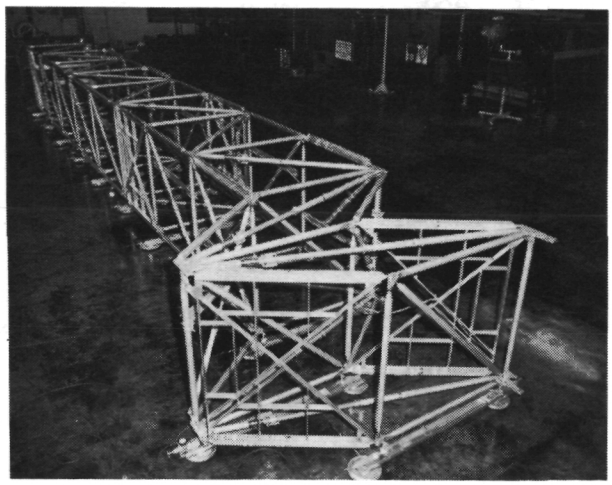

Figure 9. Deployment of the Space Deployable Truss.

SOLAR ARRAY FLIGHT EXPERIMENT (SAFE II/VOLT II)

The SAFE II flight experiment is a definitive evaluation of the operation and designs of high voltage (400 VDC) solar array in the Earth's plasma. The flight date is now planned for late 1986. Current orbital spacecraft solar arrays are limited to operating voltages of about 100 VDC.

The proposed SAFE II flight experiment, a joint NASA (LeRC and MSFC) and Air Force venture, will provide definitive and assured design approaches for future spacecraft solar-array operations at higher voltages which can then take advantage of conductor weight savings and array size reduction (reduced aero drag and consumable propellants).

In FY-83 the baseline SAFE II experiments scope was reduced to a minimum cost approach of only a high voltage array-earth plasma interaction evaluation. This concept was presented to NASA's Space Station Task Force and approved as a top priority Shuttle experiment with funding now expected. A possible additional "joint venture" experiment considering "satellite

servicing" of the array (when not at operating conditions) is under evaluation. (R. Middleton/PS04/205-453-2796)

DEPLOYABLE ANTENNA FLIGHT EXPERIMENT

Analysis in FY83 emphasized Orbiter/antenna test integration and ground test planning to augment the flight system definitions existing on 50-meter test article design, Orbiter test operations and structural measurement program. This engineering flight test addresses prevailing needs for large space sensor capabilities on future applications of microwave radiometry, multi-beam communications, spaceborne radar and radio astronomy. The antenna test article is a reuseable test-bed to support technology readiness for large phased-array apertures and parabolic reflector apertures. Both aperture configurations utilize composite structure in lightweight precision designs. This structure systems test will validate the integrated performance of several component technology thrusts undergoing development and test by NASA and DOD (precision, structural joints, lens/array membrane, large deployable mast, large mesh apertures, antenna feed systems, etc.). Developed flight hardware, such as the flight support system developed for MMS, is used for structural integration with the Orbiter.

Flight Control analyses and simulations of the Orbiter-attached antenna test have derived a combined attitude-vibration control program for structural damping and precision pointing of the large antenna system. Design concepts were also generated for ground tests on structural deployment/retraction evaluations on antenna aperture segments. The data includes preliminary test article configurations, test fixtures, instrumentation and test requirements. (W. Thompson/PS04/205-453-5746)

ORBITAL MANEUVERING VEHICLE (OMV)/REMOTE SATELLITE SERVICER

The Space Shuttle provides an efficient method of delivering and retrieving spacecraft to and from orbit. Costs are reduced because the Shuttle and the payloads can be reused many times. The efficiency of the Shuttle can be further enhanced by using a mini-space tug called OMV which has been studied at MSFC for several years. The OMV will operate in orbits higher than the Shuttle parking orbit and may also be used in GEO orbits when delivered by high energy upper stages such as Transfer Orbit Stage (TOS), Centaur and OTV. This system is closely associated with the original Teleoperator Retrieval System (TRS) which was earlier under development to reboost/deboost the Skylab.

Recent studies, both in-house and contract, have led to the definition of a highly efficient vehicle which can be used for a wide range of services. A representative configuration is pictured in Figure 11, which also depicts the use of the vehicle to support the delivery, retrieval, reboost, viewing and servicing of free-flying satellites. In addition, the OMV vehicle may be used as a transportation bus to support short-term subsatellite missions and the Space Station. Many specific configurations are being studied, but the vehicle can generally be described as a relatively thin wafer, approximately three to four feet thick and approximately 15 feet in diameter. This configuration allows it to be directly mounted to the

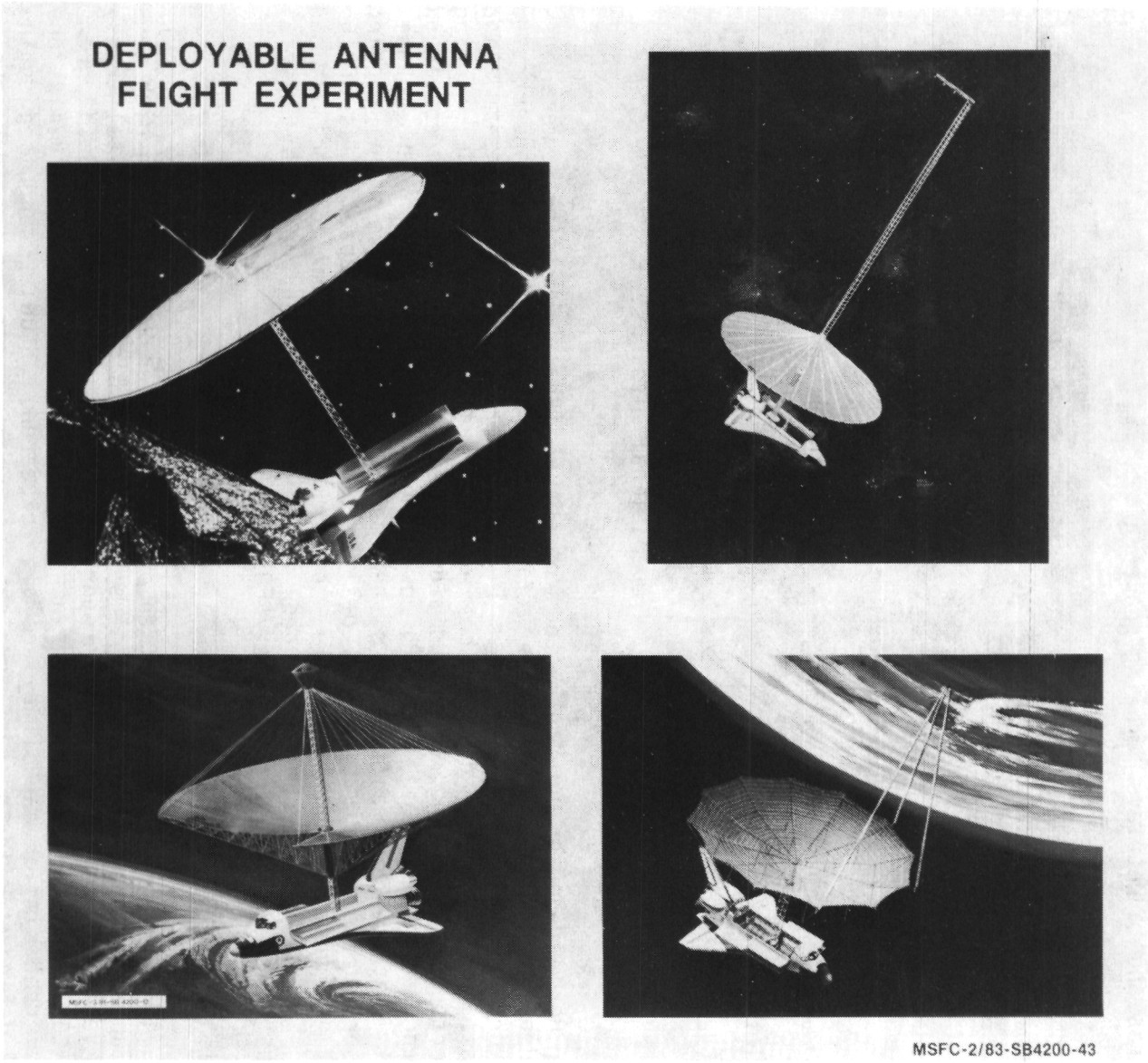

Figure 10. Deployable Antenna Flight Experiment.

Shuttle longerons and keel without the use of a cradle and thereby maximizes the Shuttle payload manfesting flexibility. The initial OMV will be controlled from the ground and later from the Space Station when it becomes operational.

Beyond the missions shown in Figure 11, many advance missions are visualized. It can support on-orbit refueling and servicing functions by the addition of mission kits consisting of refueling modules and manipulators/servicer systems capable of module exchange. In addition, specialized docking systems and/or end effectors will make it possible to collect debris and to retrieve tumbling spacecraft.

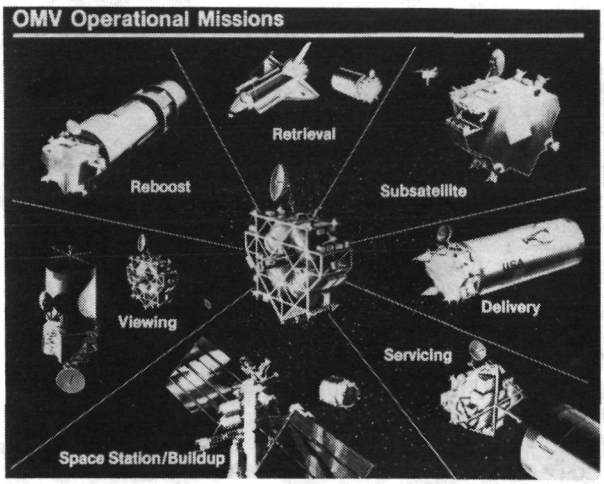

Figure 11. OMV Operational Missions.

Both in-house and contracted conceptual (Phase A) efforts were concluded in October 1983. These activities were supported by concentrated supporting development activities in the rendezvous and docking simulation areas, including the design, testing and evaluation of various docking interfaces and docking/rendezvous aids. These simulations will be continued in the definition phase (Phase B) now planned for FY84. Particular emphasis will be placed on man/machine system controls and rendezvous and docking sensors. These activities will utilize the simulation capabilities of the Docking Dynamic Simulator (6 DOF), the OMV Flat Floor Simulator Facility and the Target Motion Simulator, and will be further supported by several industrial facilities. (W. Huber/PF01/205-453-5311)

ORBITAL TRANSFER VEHICLE (OTV)

An aero-assisted version of an orbital transfer vehicle using high performance chemical propulsion systems is shown in Figure 12. Orbital transfer vehicles are needed for transporting payload of up to 7,000 kilograms between low Earth orbit and geosynchronous orbit. Interplanetary missions which need similar capability are also expected. Studies conducted during 1983 define specific mission applications, requirements and candidate evolutionary vehicle concepts. These studies have identified deployable aero-assisted vehicle concepts offering significant performance improvement for reusable transportation to geosynchronous orbit. Requirement studies showed

the need for a very short stage which can deliver a very long but substantial mass to high Earth orbit. OTV concepts which were identified utilize a toroidal oxidizer tank around the engine, thus minimizing stage length. An alternative concept involves launching the OTV in an aft cargo canister below the External Tank of the Shuttle, freeing the total Orbiter cargo bay for payloads.

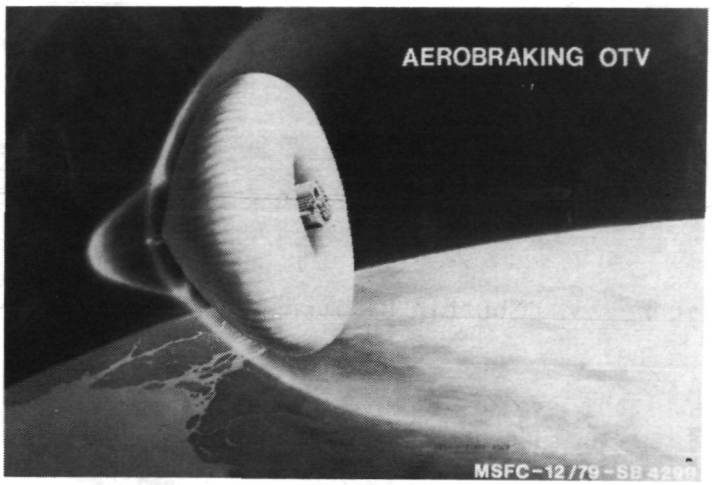

Figure 12. Aero-assisted Version of an Orbital Transfer Vehicle.

Technology studies aimed at improving the performance of cryogenic stages have been underway for several years and involve advanced engine studies and cryogenic propellant management breadboard testing. (D. Saxton/PS03/205-453-2817)

GROUND LAUNCHED TRANSPORTATION SYSTEMS

Studies of Shuttle Derived Vehicles (SDV), Figure 13, continued to investigate means to improve performance, reduce cost and increase payload volume. MSFC is investigating evolutionary vehicle concepts using Shuttle components leading to unmanned Heavy Lift Vehicles (HLLV). This approach includes investigation of Liquid Rocket Boosters (LRB) with new hydrocarbon propulsion systems, larger Solid Rocket Boosters (SRB), third stages and larger payload carriers. Replacement of the Orbiter with a cargo carrier and a recoverable, reusable propulsion/avionics module continues to be investigated as a launch vehicle with increased payload performance and increased payload volume capability. Another launch vehicle concept being investigated involves the removal of the Orbiter and the placement of a recoverable, reusable propulsion/avionics module containing a single or dual SSME under the External Tank with the payload container mounted on top of the External Tank ("in-line" configuration). The combination of Solid Rocket Motors to form an all-solid motor unmanned launch vehicle, except in a possible terminal stage (SRB-X), continues to be investigated. These Shuttle-derived vehicles could supplement the STS program.

In addition to studies to define SDV configuration options, emphasis has been placed on identification of technologies applicable to Shuttle-

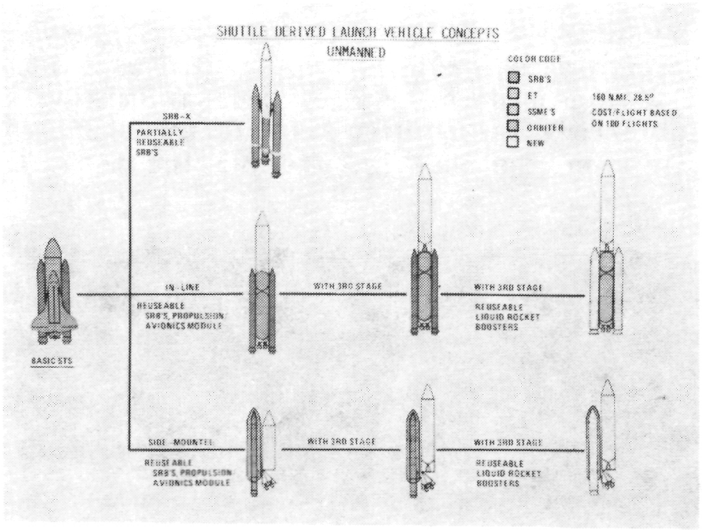

Figure 13. Shuttle Derived Launch Vehicle Concepts.

derived vehicles and the evolution to heavy lift launch vehicles. Technology areas identified include (1) LOX/hydrocarbon propulsion technology for potential application in reusable liquid rocket booster stages; (2) structures, materials and Thermal Protection Systems (TPS) technology for potential reduction in weight, turn-around time and costs; (3) avionics and recovery systems technology for lifting body and ballistic propulsion/avionics modules; (4) manufacturing and quality assurance technology for reduction in manufacturing time, testing and costs; and (5) operations technology for the reduction of vehicle turn-around requirements and launch procedures. (M. Page/PS03/205-453-2817)

TETHER APPLICATIONS IN SPACE

Research and development efforts over the past several years have resulted in the implementation of a tethered satellite system project to investigate both electrodynamic power and force generation, as well as upper atmospheric phenomena.

As an outgrowth of investigations of tethers in space, a large number and variety of other tether applications have been proposed.

A tether-applications-in-space workshop held in the summer of 1983 added more concepts, provided preliminary assessments, and defined critical issues.

A number of promising concepts are under investigation (Figure 14). Both the Smithsonian Institution and Martin Marietta Aerospace are studying the dynamics and technologies of electrodynamic tethers. The launching of payloads and upper stages by tethers and tether-mediated rendezvous have been and are being studied by Martin Marietta Aerospace and the Smithsonian Institution, respectively. The utilization of Shuttle External Tanks for orbit boost was investigated by the University of California, San Diego.

The overall program planning for FY-84 and later efforts has been performed by a NASA Tether Applications in Space Task Group for the Office of Space Flight and is continuing.

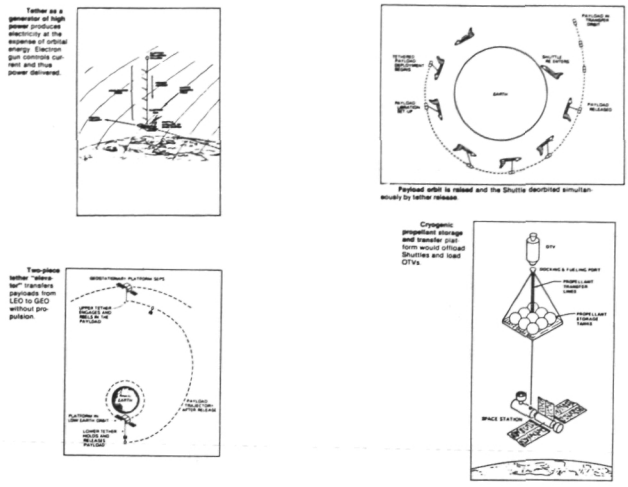

Figure 14. Concepts for Tether Applications.

Major efforts are planned in tether applications to transportation, to tethered constellations of spacecraft or payloads and to electrodynamic power generation through tethers.

Tether application investigations are a relatively new development, but so far have shown great promise in their potential to enhance mission economics in power generation, orbit change of spacecraft and improved spacecraft serviceability by cluster formation. (G. von Tiesenhausen/PS01/ 205-453-2789)

Publications:

Grossi, M. D.: "On the Feasibility of Electric Power Generation and Electromagnetic Wave Injection by Electrodynamic Tethers," Technical Note TP83-003, January 1983.

"Utilization of the External Tanks of the Space Transportation System," Contract NAS8-35037, Unviersity of California, San Diego, 1983.

"Applications of Tethers in Space, "Workshop Proceedings, June 15-17, 1983, Williamsburg, Virginia, Contract NAS8-35403.

GRAVITY PROBE-B

Although the Gravity Probe-B Program has received favorable endorsement from the National Academy of Science, OSSA, and other reviewing groups, program approval was not obtained. Subsequently, the program was restructured, with a relaxation of some instrument requirements and some hardware redesign. The restructured program promises both a shortened schedule and reduced program costs. If the program is approved in the FY-85 budget request, it will be possible to have a mission start in FY-88. Planning on this restructured program is being altered to include provisions for an early Shuttle flight experiment which will demonstrate several of the more

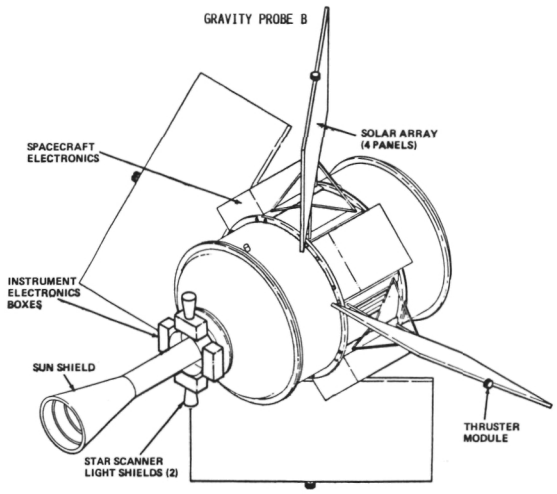

Figure 15. Gravity Probe-B.

critical technology areas and will provide some systems performance flight data prior to a commitment to the actual science mission.

Advanced development efforts at Stanford and MSFC are continuing. Considerable progress was made in depositing very uniform thin niobium coatings on the quartz rotors. A new suspension system for levitating the rotors was designed and built, and is being tested. Dewar insulation techniques and determination of porous plug performance characteristics are being evaluated. (A. Neighbors/PF16/205-453-5584)

Publication:

Gravity Probe-B Phase B Final Report, Volumes I, II, III, and IV, February 1983.

LARGE INTERFEROMETERS IN SPACE

Availability of the Space Telescope will assure that space astronomy in the 1980's will continue to make exciting discoveries. These findings will, as always, raise new questions that require the use of even more powerful astronomical instruments in order to understand these new phenomena. To meet these needs, large astronomical facilities with greatly improved angular resolution and larger collecting areas will be placed in space above the absorbing and distorting interference of the Earth's atmosphere.

The capability to assemble large structures in space and the existence of advanced technology for maintaining precise baselines and accurate pointing of large systems will make it possible to base high-resolution interferometers in space. Technologies now being developed in the Large Space Structures Program contribute key enabling technologies for development of large baseline interferometers. Two such concepts which make use of these advanced technologies are currently under study by the Marshall Space Flight Center: The orbiting Very Long Baseline Interferometer (VLBI) and a phase-coherent UV/visible telescope array.

Extending VLBI to Space

Radio interferometry observations of celestial sources are routinely performed on Earth by using atomic frequency standards to synchronize radio telescopes that may be separated by as much as intercontinental distances. Angular resolution of magnitude superior to that of Earth-based optical telescopes has been achieved. By placing one or more of the observing elements in Earth orbit and making observations in concert with those on the ground, significant advantages over purely ground-based systems can be obtained.

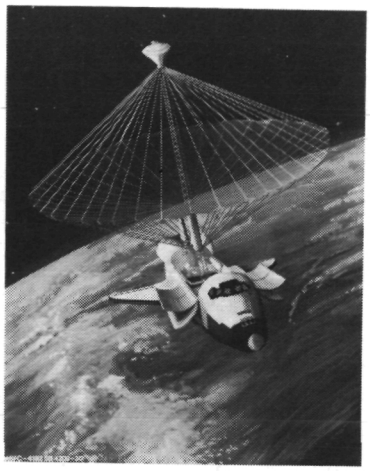

Figure 16. Very Long Baseline Interferometer-Retrievable Space Antenna.

An initial step would be to utilize the capability of the Space Shuttle to demonstrate orbiting VLBI by deploying a large retrievable antenna attached to the Shuttle. This mission could be part of the Large Deployable Antenna Flight Experiment that has been under active study by MSFC and aerospace contractors during the past several years. This flight would provide an on-orbit test of a large (50 meter) antenna system (which also has potential applications in defense, communications and Earth observations among others). An artist's concept of one possible antenna is shown in Figure 16. During the mission about three days would be devoted to VLBI observations. An alternative system now under study at MSFC is a 15 meter antenna aboard the Shuttle that could later be used on the Space Platform or perhaps on an Explorer class mission. Although a larger aperture antenna is desirable, an important set of bright sources could be observed with a space antenna as small as 5- to 10-meters in diameter.

During 1981, a technical working group was established to assist in the science and mission design of a VLBI experiment. Scientific objectives and mission and system/subsystem requirements for performing a VLBI demonstration have been established.

In 1983, the working group met in Toulouse, France, to discuss potential cooperation with scientists at CNES (National Space Research Center). ESA is also funding studies to use Viking spacecraft in highly elliptical orbits. Study efforts at MSFC are currently concentrating on a realistic cost assessment for a VLBI demonstration using an existing antenna built for deployment tests by Harris Corporation for Langley Research Center. (M. Nein/PS02/205-453-3430)

Publications:

Morgan, S. H. and Roberts, D. H. (editors): "Shuttle VLBI Experiment: Technical Working Group Summary Report," NASA TM-8249, NASA-George C. Marshall Space Flight Center, July 1982.

Preston, R. A., Burke, B. F., Dozsey, F., Jordan, J. F., Morgan, S. H., Roberts, D. H. and Shapiro, I. I.: "The Future of VLBI Observatories in Space," International Conference on VLBI Techniques, Centre National D'Etudes Spatiales, Toulouse, France, September 1982.

ADVANCED X-RAY ASTROPHYSICS FACILITY (AXAF)

Technology related activities in support of AXAF in FY 1983 were concentrated in the area of X-ray optics. The two major contracts for this effort are with Perkin-Elmer and Itek. Significant progress has been made at both locations in the fabrication of Technology Mirror Assembly (TMA) hardware. Based on current schedules, the TMA's will be available for testing at MSFC in late 1984. Data from X-ray tests will be made available to Phase B contractors for their use in completing preliminary design of the AXAF, and will assist the Project Office in establishing realistic specifications for the development phase. Figure 17 shows one of the glass optical elements being ground on the inside surface at Itek.

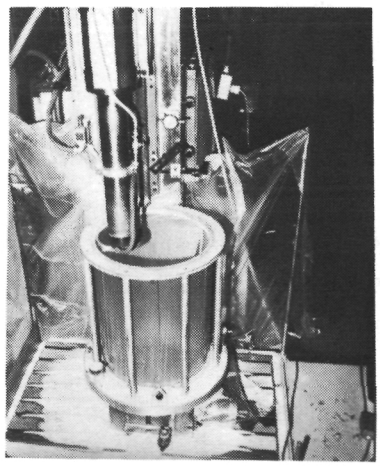

Figure 17. Mirror Element Undergoing Grinding Operation at Itek.

At MSFC, progress has been made in preparing the X-ray test and calibration facility for the TMA tests. Preparations include modification of some handling equipment, additional viewports and electrical feed-throughs in the vacuum chamber and other relatively minor changes. Also, an array of detectors is being assembled into a special fixture which can be translated along the axis to obtain precise information on the X-ray image. Figure 18 shows the breadboard High Resolution Imager (from the HEAO-1 program), which

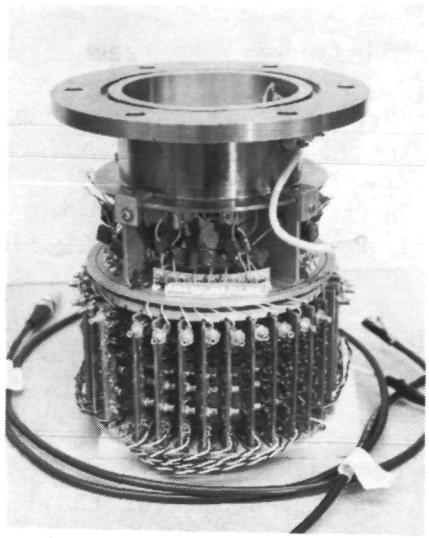

Figure 18. Breadboard High Resolution Imager for TMA X-Ray Testing.

will be one of the key detectors for evaluating the performance of the contractor's TMA's. Figure 19 shows the fixture prior to installation of the detectors.

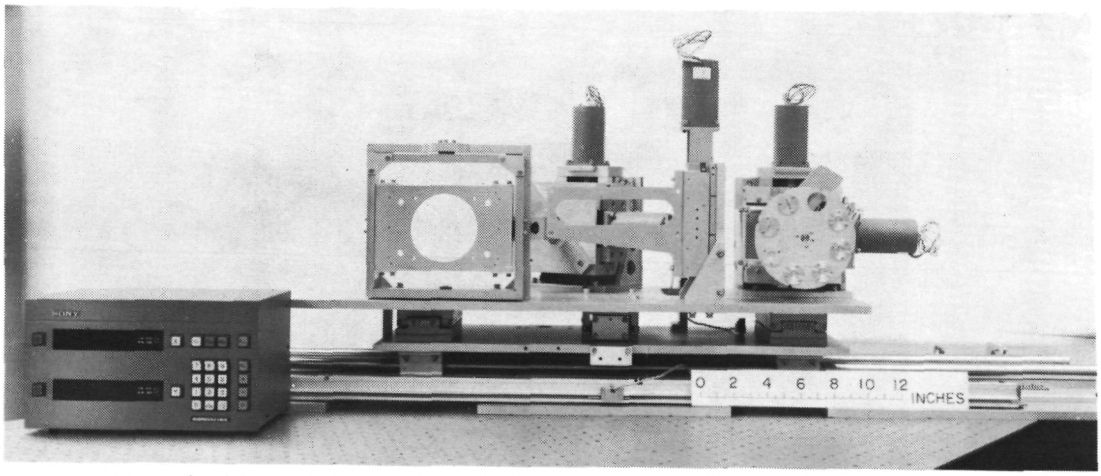

Figure 19. Detector Holding Fixture for X-Ray Testing.

A data system (not shown) will act as a controller of the detector and fixture mechanisms, accumulate the data, and process it into a form in which it can be readily interpreted. This system has been delivered and the software is being generated. An attractive feature of the data system and detector setup is that it can be used in the testing program for the flight mirror system for AXAF.

Two significant program milestones were reached with the release of the Announcement of Opportunity (AO) in August and in the release in November of the Phase B RFP (Request for Proposals) for two or more systems definition contracts for the overall observatory. A one year Phase A study was completed and documented, and a special study on orbital maintenance and repair was initiated. An industry briefing and a briefing for potential experimenters were held as part of the AO process. (C. Dailey/PS01/205-453-2788)

PINHOLE OCCULTER FACILITY (POF)

The POF (Figure 20) is an observatory imaging the sun and celestial objects in hard X-rays and observing the solar corona in visible and ultraviolet wave lengths. It is initially to be flown as a Shuttle-based payload, with eventual inclusion in semi-permanent facilities such as the Space Station. The POF utilizes a 35-meter deployable boom of an existing design to position an occulting mask between the solar instruments and the solar disk. The coronal imaging instruments observe the solar corona around the edge of the disk, while multiple aperture imaging systems observe the hard X-ray activity of the sun. The imaging systems, occulting mask and deployable boom are pointed and stabilized by the Instrument Pointing System (IPS). The system functioning in the celestial observing mode can be used to form high resolution images of celestial objects in much higher energies than previously possible.

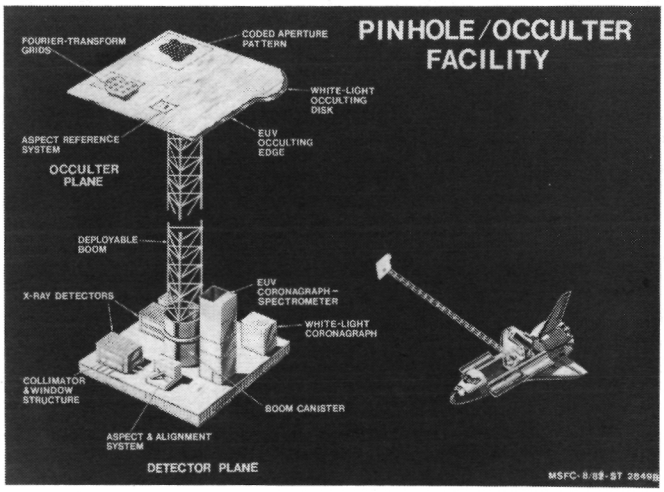

Figure 20. Pinhole Occulter Facility (POF).

An in-house Phase A feasibility study was carried out in 1983 with final documentation anticipated in 1984. Primary areas of concern include layout and instrument accommodation studies, aspect and alignment studies and control law implementation studies utilizing the IPS and associated subsystems. (J. Dabbs/PS02/205-453-3430)

Publications:

Dabbs, J. R., Tandberg-Hanssen, E. A. and Hudson, H. S.: "The Pinhole/Occulter Facility Executive Summary," NASA TP-2089, October 1982.

Tandberg-Hanssen, E. A., Hudson, H. S., Dabbs, J. R. and Baity, W. A.: "The Pinhole/Occulter Facility," NASA TP-2168, April 1983.

SPACE BASE COHERENT OPTICAL SYSTEM OF MODULAR IMAGING COLLECTORS (COSMIC)

Increased collecting area and higher overall precision to achieve higher resolution are the principal requirements for the advanced telescopes of the future. To increase the collecting area by simply scaling conventional telescope configurations seems to have reached its limits with the ST on one hand and the largest existing ground-based telescopes on the other hand. Of all new design concepts, the segmented mirror and phased array telescopes have attracted most of the attention.

To achieve high performance most economically, while complying with physical constraints imposed upon the overall system by the available Shuttle payload space and weight limitations, unconventional aperture shapes, such as elongated or partially filled apertures, are also being investigated.

In spite of the high degree of complexity, phased array telescopes have some definite advantages which warrant further investigation. For instance, the linear arrangement of the telescope is particularly suitable for storage in the Shuttle payload bay. The second major advantage is its potential to yield the highest possible resolution for any given collecting areas. Even though maximum resolution is instantaneously obtained in only one dimension, a two-dimensional point spread function yielding high resolution may be synthesized by rotating the aperture.

Because of these primary reasons, linear phased arrays have been analyzed as potential next generation UV/optical telescope systems. Some of the system considerations resulting from this study are presented here.

Figure 21 shows an artist's concept of COSMIC and the evolutionary construction of a large cruciform array. The initial array contains four Afocal Interferometric Telescopes (AIT) with a Beam Combining Telescope (BCT) at one end. The COSMIC spacecraft module pivots from its launch position at the end of the BCT to its deployed position below the BCT. The solar arrays deploy from stowed positions alongside the telescope module. The focal planes of the BCT and sun-shades are extended above the telescope apertures.

In 1983 a study of different concepts for COSMIC was completed in-house to investigate various telescope configurations and launch options based on the assumption that a long baseline is more important than light-gathering capability. The concept is to package two parrallel arrays in the payload bay that can be deployed on orbit into one long baseline configuration.

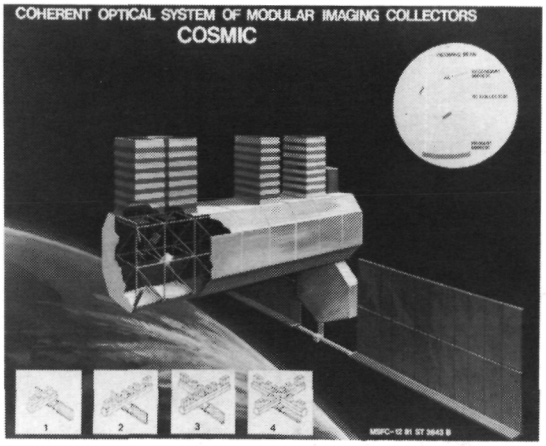

Figure 21. Coherent Optical System of Modular Imaging Collectors (COSMIC).

The subsystems, BCT and SI, are packaged into one module. The two arrays are attached to the module at launch and are rotated into position on orbit. The optical sizes are parameterized to obtain a long baseline and to let the AIT optical size be secondary in importance. When deployed, it has a 28 m baseline and 8 AIT's with 1.13 m diameter primaries. The projected resolution for this system is about 0.005 arc sec. Enough space exists along the array to add six additional collecting telescopes. The sunshades must be fully deployable in design. The deployed size of the main body is 7-ft. diameter by 94 ft. long.

The Smithsonian Astrophysical Observatory is assisting NASA in the definition and analyses of the image reconstruction methods. Scientific objectives have been established and mission and system requirements have been established. (M. Nein/PS02/205-453-3430)

Publications:

Nein, M. E. and Davis, B. G.: "Conceptual Design of a Coherent Optical System of Modular Imaging Collectors (COSMIC)," in Advanced Technology Optical Telescopes, SPIE, 1982.

Davis, B., Hunt, G., Korsch, D. and Nein, M.: "Coherent Optical System of Modular Imaging Collectors (COSMIC): An Approach for a Large Aperture High Angular Resolution Telescope in Space," to appear in 1983, SPIE Proceedings, Vol. 440, Synthetic Aperture Systems.

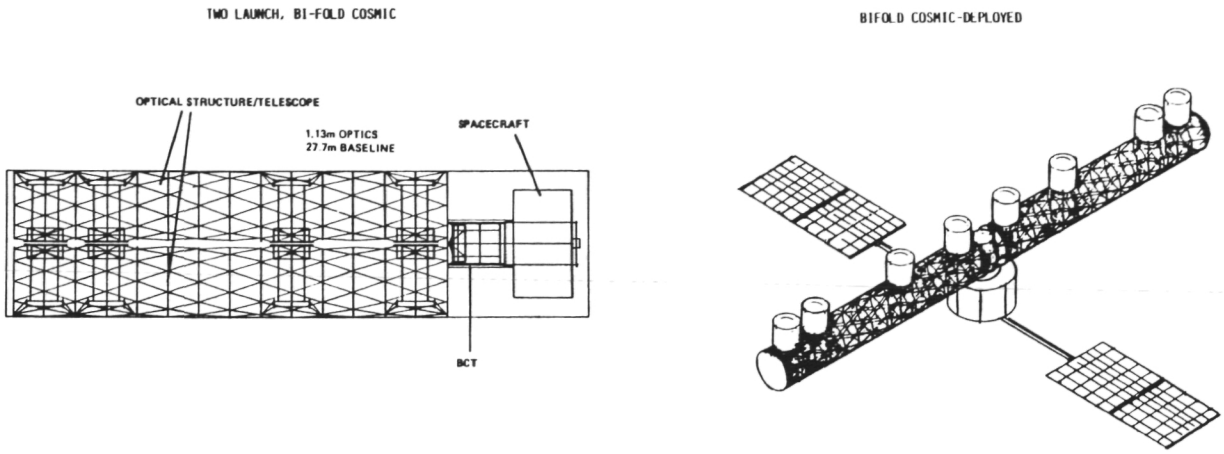

Figure 22. Bi-Fold COSMIC Telescope Concept.

ATMOSPHERIC SCIENCES

Global Atmospheric Processes

Utilization of Satellite Data

In their observational study of the index cycle (quasi-periodic variations of tropospheric winds and temperature gradients), performed under an MSFC contract, Clark and Dutton have found that the barotropic conversion of wave to mean flow energy, and vice versa, is well correlated with the stability of the mean flow. This barotropic instability is the driving mechanism for the index oscillation. It was also found that radiation heating and cooling at high latitudes, as measured by the NIMBUS-6, Earth Radiation Budget Satellite, does amplify the oscillations through a positive feedback mechanism involving high latitude cloud cover. The reports listed below were generated during this study. (J. Clark and J. Dutton, Pennsylvania State University/814-863-1581)

Publications:

Dutton, J. A., Clark, J.H.E. and Shirer, H. N.: "Causes and Prediction of Zonal Wind Intensity," NASA Conference Publication 2281, NASA/MSFC FY-83 Atmos. Proc.Research Review, compiled by Dr. R. E. Turner, MSFC, Huntsville, Alabama, May 24-25, 1983.

Clark, J.H.E.: "The Effect of Topograph on the Long-Term Evolution of Baroclinic Waves," submitted to the Jour. of Atmos. Sci.

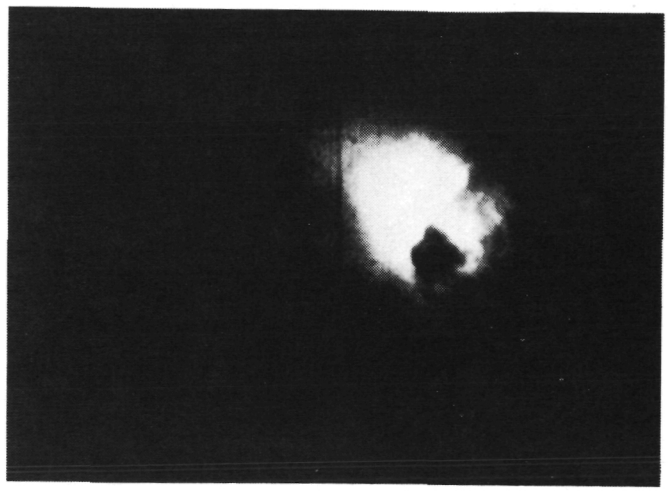

Figure 23. Typical Cloud Top Flash Recorded on STS-6.

Nighttime/Daytime Optical Survey of Lightning Experiment (NOSL)

This experiment, flown and operated by the astronauts on STS-6, was a reflight of the NOSL experiment which also was flown on STS-4. Lightning flashes as large as four miles in diameter, a much larger area than expected from ground-based observations, were recorded on the ASA 400 film. This low-light level film was used specifically for this flight to obtain better flash detail. Data, both photo and electronic, were obtained on storms over the west coast of Africa and over the Gulf Coast of the U.S. for both nighttime and daytime lightning. Twenty-eight electronic signatures were recorded in the nineteen minutes of actual experiment time. This was the first time positive correlations were obtained for the electronic signatures with the photographic data for the nighttime flashes. Figure 23 shows a typical cloud top flash which was recorded on STS-6.

Range Reference Atmosphere Models

During the past year statistical atmospheric models have been developed and published for 12 geographical locations by the Range Commanders Council Range Reference Atmosphere Committee under the leadership of O. E. Smith, ED41, who was also chairman and a major contributor. These models will be used in all studies and analyses that require environmental inputs. The location of these 12 range reference atmospheres are given in Table 1.

TABLE 1

LOCATION	ALTITUDE RANGE
AFFTC/Edwards AFB, CA	0-70 km
ESMC/Cape Canaveral AFS, FL	0-70 km
WSMC/Vanderberg AFB, CA	0-70 km
WSMR/White Sands, NM	0-70 km
PMTC/Point Mugu, CA	0-70 km
UTTR/Dugway (Michales AAF), UT	0-30 km
AD/Eglin AFB, FL	0-30 km
ESMC/Ascension Island	0-66 km
NASA/Wallops Flight Center, VA	0-70 km
TAQUAC (Guam)	0-30 km
PMTC/Barking Sands, HI	0-70 km

Wind is modeled as a vector quantity using the bivariate normal probability function. Using the five-parameters of the bivariate normal distribution, the distribution for wind speed is derived as a generalized Rayleigh distribution, the frequency of wind direction is derived and the conditional distribution of wind speed given the wind direction (wind rose) is derived. These and other wind models are consistent with rigorous mathematical properties of the bivariate normal probability theory.

The thermodynamic quantities statistics are modeled to be consistent, insofar as practical, with the Hydrostatic equation, the equation of state and the probability principles which are related through these physical

equations. The derived correlation coefficients among pressure, temperature and density are illustrated. The range reference atmospheres have broad applications for aerospace flight vehicles. The techniques used in developing these atmospheric models have important contributions in efficient computations of upper atmospheric statistics and in establishing consistent upper air climatologies. Papers listed below were published as a result of this activity. (O. Smith/ED41/205-453-3101)

Publications:

Smith, O. E. and Galusha, B. W.: "Range Reference Atmosphere Models," to appear in conference proceedings of Eight Conference on Probability and Statistics, Americian Meteorological Society, Hot Springs, Arkansas, November 16-18, 1983.

Participating Individuals: Cochairmen/The Range Reference Atmosphere Committee, O. E. Smith/ED41, and Major B. W. Galusha, USAF Environmental Technical Application Center, Scott AFB, Illinois.

Mesoscale Atmospheric Processes

Use of Satellite Data

The influence of cumulus convection on baroclinic disturbances in middle latitudes is to provide a net thermodynamic heating and vertical flux of total eddy heat. Geostationary Operational Environmental Satellite (GOES) visible and infrared digital data have been combined with precipitation measured at the ground to diagnose the magnitude of this forcing. The heating estimates from two case studies show middle to upper tropospheric maxima with stratospheric cooling associated with overshooting anvil cloud tops.

These heating measurements have been incorporated into a new diagnostic model of Available Potential Energy (APE) in isobaric coordinates. The results indicate that differential heating by convection is an important source of APE which is then converted into kinetic energy on this cyclone-scale. The new APE formulation also allows an evaluation of APE changes in a mechanically open environment where boundary work and transports are present. Unlike earlier pressure coordinate formulations, this version contains no explicit temporal derivatives of reference pressure and is therefore more reliably computed from observed atmospheric temperature and winds. Papers published as a result of this effort are listed below. (F. Robertson/ED42/205-453-1944 and P. Smith/Purdue University/317-494-3285)

Publication:

Cumulus-Scale Heating and Its Influence on MesoDynamics during AVE/SESAME I, 13th Severe Storms Conference Preprints, Tulsa, Oklahoma, October 17-20, 1983.

Ionosphere-Severe Storms Coupling

The Atmospheric Sciences Division is investigating techniques for the early detection or identification of areas where atmospheric conditions favor the development of severe storms. During the past year case studies of severe storms have shown that tornadoes are more likely to occur in those areas where the height of the tropopause is decreasing rapidly. It may be possible to use observations from space that can pinpoint areas where the cloud top temperature over an extensive region is decreasing rapidly while the tropopause temperature is rapidly increasing to provide an early warning of severe storm activity. This work has been documented in the following publications. (R. Smith/ED41/205-453-3101 and R. Hung/UAH/205-895-6077)

Publications:

Smith, R. E. (with Hung, R. J.): "Remote Sensing of Tornadic Storms from Geosynchronous Satellite Infrared Digital Data," Int. J. Remote Sensing, 3, pp. 69-81, 1982.

Smith, R. E. (with Hung, R. J.): "Fluid Mechanics Simulation of the Effect of Combustion-Related Pollutants on the Fog Formation," Developments in Theo. and Applied Mechanics, 11, pp. 435-456, 1982.

Smith, R. E. (with Hung, R. J.): "Satellite Infrared Imagery, Rawinsonde Data and Gravity Wave Remote Sensing of Severe Convective Storms," Int. J. Infrared and Millimeter Waves, 3, pp. 489-502, 1982.

Smith, R. E. (with Hung, R. J.): "Remote Sensing of Tornadic Storms from Space," Space Simulation, 12, pp. 259-270, 1982.

Smith, R. E. (with Hung, R. J.) Agee, E. M. and Asai, D. (editors): "Detection of Convective Storms Based on Penetrative Cloud Top from Satellite Infrared and Rawinsonde Data and Gravity Waves from Doppler Sounder," Cloud Dynamics, D. Reidel Publishing Co., Amsterdam, The Netherlands, pp. 347-362, 1982.

Smith, R. E., Cook, J. J. (editor) (with Hung, R. J.): "Severe Convective Storm Detection Based on Satellite Infrared Imagery Analysis," will appear in Proc. 16th Int. Sympos. on Remote Sensing on Environ., University of Michigan, Ann Arbor, Michigan, 1982.

Smith, R. E., Henderson-Sellers, A. (with Hung, R. J.): "Remote Sensing of Severe Storms from Geosynchronous Satellite," Remote Sensing and the Atmos., pp. 283-291, Remote Sensing Society, University of Reading, United Kingdom, 1982.

Smith, R. E. (with Hung, R. J.): "Overshooting Cloud-Top Penetrated Above the Tropopause and the Severe Storm Formation," Trans. Am. Geophys. Union, 64, p. 201, 1983.

Smith, R. E. (with Hung, R. J.): "Study of Severe Storm Development Based on Satellite, Rawinsonde Data Analysis," NASA/MSFC FY-83 Atmos. Proc. Rsch. Review, NASA Conference Publication No. 2259, pp. 99-101, NASA Headquarters, Washington, D. C., 1983.

Smith, R. E. (with Hung, R. J.): "Relationship Between Severe Storm Development, Tropopause Heights and Overshooting Cloud Tops," NASA/MSFC FY83 Atmos. Proc. Rsch. Review, NASA Conference Publication No. 2281, pp. 126-128, NASA Headquarters, Washington, D. C., 1983.

Smith, R. E. (with Hung, R. J.): "Remote Sensing of Arkansas Tornadoes on April 11, 1976, from a Satellite, a Balloon and an Ionospheric Sounder Array," Init. J. Remote Sensing, 4, pp. 617-630, 1983.

Smith, R. E. (with Hung, R. J.): "Numerical Simulation of Fog Formation and Liquid Water Content and Polydisperse Multi-Composition Aerosols due to Combustion-Related Pollutants, J. Environ. Sci., 24, pp. 44-48, 1983.

Smith, R. E. (with Hung, R. J.): "Computer Image Processing of Up-draft Flow Motion and Severe Storm Formation Observed from Satellite," Flow Visualization, 3, pp. 173-180, 1983.

Smith, R. E. (with Hung, R. J.): "The Life Cycle of a Tornadic Cloud as Seen from a Geosynchronous Satellite," AIAA Journal, 21, pp. 1217-1224, 1983.

Smith, R. E. (with Hung, R. J.): "Case Study of the March 24, 1976, Elton, Louisiana Tornado Using Satellite Infrared Imagery, Doppler Sounder, Rawinsonde and Radar Observations," Int. J. Infrared and Millimeter Waves, 4, pp. 375-400, 1983.

Geophysical Fluid Dynamics

Fluid Interface and Bubble Experiment (FIBEX)

Equilibrium free surface shapes of rotating liquids play a key role in spacecraft fuel tank design and fluid management systems. Recently, further research in this area has been motivated by the gravity probe-B liquid helium management problem in which the superfluid must be distributed in such a manner that it is gravitationally symmetric about a fixed proof mass. With the analysis of Dr. Roger Gaas (University of Rochester), design constraints were established for such partially filled rotating containers using baffles. Computations were made for the steady state interface position with various container configurations and rotation rates. Two types of instability became apparent from these results. For high rotation rates compared to surface tension forces, the fluid was centrifuge-flat against the container wall. For lower rotation rates, a meniscus forms which intersects the boundaries. However, for very low rotation rates, the surface forces dominate, and the interface rolls up, forming a bubble whose position is uncertain. A second type of instability results for adjacent baffles connected at their bottom. For particular parameter values determined from calculations, the downward displacement of one column produces a rise in the second column that is unstable and continues rising. This rise is due to the increase in surface tension pressure of the second column over the hydrostatic pressure. Laboratory experiments were carried out to verify the calculations of the free surface shapes. The data agreed well with the

computations within the parameter range attainable. A real test of the important terms of the equation, however, requires that the surface tension be of the same magnitude as the centrigugal force and much greater than the gravitational forces with a rapidly rotating container. However, in order to bring surface tension forces up comparably, the dimensions would have to be impractically small. Instead, gravity was eliminated from the problem by designing a low-gravity experiment to be operated aboard the KC-135 aircraft. The design is composed of a baffled test cell mounted on a turntable and gimballed to eliminate aircraft pitching moments. Fabrication of the hardware has begun. This work was reported at the Space Helium Dewar Conference and Workshop. (F. Leslie/ED42/205-453-2047 and C. Schafer/ED42/205-453-1886)

New Statistical Model for Wind Gusts

The development of a bivariate gamma probability distribution and the development of a new discrete wind gust model are both considered original and significant research accomplishments. In 1981 Smith and Adelfang published in the AIAA Journal of Spacecraft a new wind gust model. This gust model related gust magnitude and gust length under the assumption of equal shape parameters of the four-parameter bivariate gamma distribution. This assumption proved to be inadequate to properly describe the wind gust data sample. Since then a five-parameter bivariate gamma distribution having two shape parameters, two location parameters and a correlation parameter has been developed. The general bivariate gamma distribution reduces to the known four-parameter distribution. The five-parameter distribution gives a better fit to the gust data. The statistical properties of this general bivariate gamma distribution and a hypothesis test have been investigated as noted in the references. Although these developments have come too late in the Shuttle program to be used directly as design criteria for ascent wind gust loads, the new wind gust model has helped to explain the wind profile conditions which cause large dynamic loads. Other potential applications of the newly developed five-parameter bivariate gamma distribution are in the areas of reliability theory, signal noise and vibrations mechanics.

Contributors to this research are Drs. Tubbs and Brewer from the University of Arkansas and Dr. Adelfang from the CSC Applied Technology Division of Huntsville, AL. (O. Smith/ED41/205-453-3101)

Publications:

Smith, O. E. and Adelfang, S. I.: "A Gust Model Based on the Bivariate Gamma Distribution," J. Spacecraft, Vol. 18, No. 6, pp. 545-549, 1981.

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Smith, O. E., Adelfang, S. I. and Tubbs, J. D.: "Computational Results for the Five-Parameter Bivariate Gamma Distribution with Application to Gust Modeling," under review Communications in Statistics, B.

Tubbs, J. D. and Smith, O. E.: "A Note on the Ratio of Correlated Gamma Variates," accepted for publication in Communications in Statistics, A, Theory and Methods, 1983.

Tubbs, J. D.: "Testing for Equality of Shape Parameters in the Bivariate Gamma Distribution," submitted to JASA, 1983.

Brewer, D. W.: "A Differential Equation for the Model Location for a Family of Bivariate Gamma Distributions," submitted to SIAM Journal on Scientific and Sta-tistical Computing, 1983.

The experiment PI was Dr. B. Vonnegut, State University of New York at Albany, New York. Co-I's were Mr. O. H. Vaughan, Jr., Atmospheric Sciences Division, Systems Dynamics Laboratory, MSFC, and Dr. Marx Brook, New Mexico Institute of Mining and Technology, Socorro, New Mexico. (O. Vaughan/ED43/205-435-5218, B. Vonnegut/SUNYA/518-457-4607 and M. Brook/NMIT/505-835-5611)

Shuttle Exhaust Cloud Properties

A data base describing the properties of the exhaust cloud produced by the launch of the Space Transportation System and the acidic fallout observed after each of the first four launches was assembled from a series of ground and aircraft based measurements made during the launches of STS-2, -3, and -4. Additional data were obtained from recent ground-based measurements during firings of the 6.4 percent acoustic model of the Solid Rocket Booster at the Marshall Center. Analysis has led to an understanding of the production and transport mechanisms of the fallout and illumination of many aspects of the exhaust/environment interaction. Results have been documented in a NASA technical paper (in press) and the following papers. (B. Anderson and V. Keller/ED43/205-453-5218)

Publications:

Keller, V. W. and Anderson, B. J.: "Microphysical Properties of the Shuttle Exhaust Cloud," Ninth Conference on Aerospace and Aeronautical Meteorology, Omaha, Nebraska, March 1983.

Anderson, B. J. and Keller, V. W.: "An Application of Model Testing for the Study of Rocket Exhause Cloud Properties," Ninth Conference on Aerospace and Aeronautical Meteorology, Omaha, Nebraska, March 1983.

SPACE SCIENCES

Solar Physics

Ultraviolet Spectrometer and Polarimeter (UVSP)

The UVSP is orbiting Earth aboard the Solar Maximum Mission (SMM) satellite, but operation of the SMM's narrow field of view instruments was prematurely interrupted in late 1980 by the loss of the satellite's accurate pointing control. Repair of the attitude control system, refurbishment of some instruments, and redeployment of the satellite will be attempted in 1984. In the meantime, analyses of the SMM data obtained during the first active phase continue at MSFC and elsewhere. The international Solar Maximum Year (SMY) program of coordinated observation and analysis has become a

Solar Maximum Analysis (SMA) program, with gatherings and workshops planned in conjunction with international meetings of other organizations; in the United States, two SMM workshop sessions have been held in 1983 to foster collaborative investigations of events observed by the SMM experimenters and by ground-based observers. The final session will be held in February 1984. Our data analyses emphasize the observations obtained with MSFC's ground-based (UVSP) and Coronagraph/Polarimeter (C/P) instruments aboard the SMM.

The onset and impulsive phase of a fairly large (1B, M1.2), but simple two-ribbon solar flare on November 1, 1983, was analyzed in conjunction with other types of data. The observations consisted of hard X-ray flux measured by the Hard X-ray Burst Spectrometer (HXRBS) instrument aboard SSM, high-sensitivity measurements of microwave flux at 22 GH_z from Itapetinga Radio Observatory, sequences of spectroheliograms in UV emission lines from O V ($T = 2 \times 10^5$ K) and Fe XXI ($T = 10^6$ K) from the SMM UVSP, H-alpha and He I D3 cine-filtergrams from Big Bear Solar Observatory, and a magnetogram of the flare region from the MSFC Solar Observatory. From these data, we concluded the following:

a. The overall magnetic field configuration in which the flare occurred was a fairly simple closed arch containing nonpotential substructure.

b. The flare occurred "spontaneously" within the arch; it was not triggered by emerging magnetic flux.

c. The impulsive energy release occurred in two major spikes. The second spike took place within the flare arch heated during the first spike, but was concentrated on a different subset of field lines. The ratio of O V emission to hard X-ray emission decreased by at least a factor of 2 from the first spike to the second, probably because the plasma density in the flare arch had increased by chromospheric evaporation.

d. The impulsive energy release most likely occurred in the upper part of the arch; it had three immediate products:

(1) An increase in the plasma pressure throughout the flare arch by at least a factor of 10.

(2) Nonthermal energetic (25 keV) electrons which impacted at the feet of the arch to produce the hard X-ray burst and impulsive brightening in O V and D3.

(3) Another population of high-energy (100 keV) electrons (decoupled from the population that produced the hard X-rays) that produced the later, impulsive microwave emission at 22 GHz. Figure 24 shows that the microwave peak lagged the X-ray peak by more than any reasonable transit time of the responsible energetic particles. This work was done in collaboration with colleagues at Instituto de Pesquisas Espaciais, Brazil; Goddard Space Flight Center; and Big Bear Solar Observatory, Caltech.

The solar transition zone in the neighborhood of filaments has also been studied. The measured Doppler shifts of the C IV line at 1548 Å and Si IV line at 1393 Å, formed a $T = 10^5$ K, yield a general updraft of 5 to 15 km/s around quiescent filaments relative to the average for the transition zone. This work was done in collaboration with a colleague at Institute of Theoretical Astrophysics, Oslo, Norway.

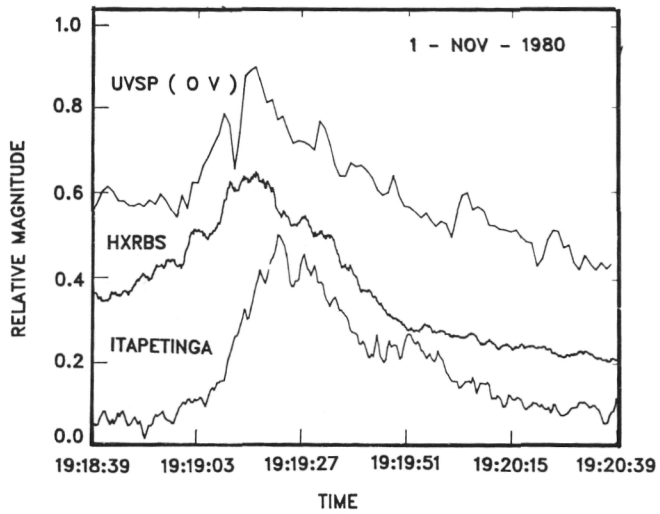

Figure 24. Light curves for second spike of impulsive phase of a flare on November 1, 1980. The O V data are plotted each 1.2 sec; the hard X-ray (HXRBS) data at 0.128 sec resolution; and the 22 GHz (Itapatinga) radio data each 0.4 sec. The 22 GHz peak lags the O V and hard X-ray peaks by several seconds.

To infer velocities and longitudinal magnetic fields from signals measured with UVSP, it is necessary to know the width of the emission line being used. Even if calibration sequences were not performed, it is possible to use the line-of-sight component of the spacecraft orbital velocity to infer the line width for each pixel in a raster if (1) the duration of the observing sequence covered a large enough fraction of the spacecraft orbit, (2) there were no large secular or long-duration changes in the velocity in the solar emitting region, and (3) the line width could be considered to be constant during the observation. A least-squares fit of the observed Doppler signal to the line-of-sight component of the spacecraft velocity technique was developed and then applied to a magnetogram observation to determine line widths. These widths were then used to obtain improved values for the longitudinal magnetic field where an assumed line width had previously been used. Figure 25 illustrates the application of the method to observations of a sunspot. As can be seen, the least-squares technique is able to fit quite well the overall change in the observed signal to the spacecraft velocity. (E. A. Tandberg-Hassen/ES02/205-453-0027)

Publications:

Henze, W., Tandberg-Hanssen, E., Reichmann, E. J. and Athay, R. G.: "SMM/UVSP Observations of the Distribution of Transition Region Oscillations and Other Properties in a Sunspot," Solar Phys (submitted).

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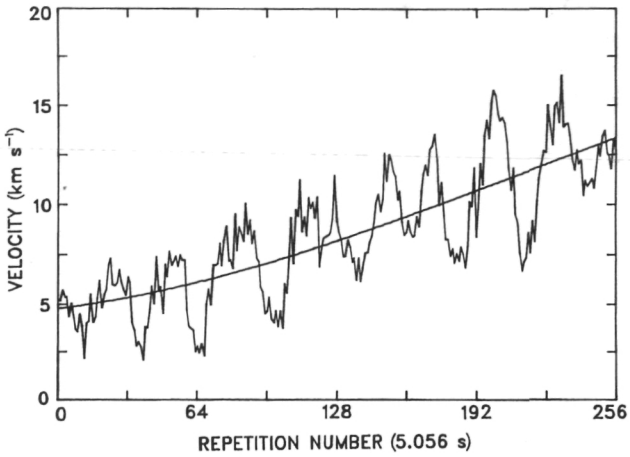

Figure 25. Example of application of calibration method for UVSP dopplergrams and magnetograms using spacecraft motion. The smooth curve is in the line-of-sight component of the orbital motion. The irregular curve is the observed Doppler shift signal converted to velocity using the Doppler width determined by the method. The zero point of the velocity scale is determined by the position of the spectrometer grating so that the plotted velocities include a vertical offset which is also determined by the method.

Solar Magnetic Fields

The upgrading program for the MSFC solar vector magnetograph has been completed. This project involved the installation of a CCD camera, an electronic control system interfaced with a computer, and a new polarimeter. Initial observations indicate that the increased sensitivity of the new system allows detection of 2-3 gauss line-of-sight fields. Figure 26 shows the optics box in its new configuration. Extensive operations are planned in support of the SMM observations when they resume in 1984.

The objective of this research program is to determine and understand basic empirical properties of solar magnetic fields and their effects in the solar atmosphere. The approach is to analyze MSFC vector magnetograms along with complementary data from other observatories and from the SMM, especially from the UVSP, and to interpret the observed effects with physical models. The problems pursued are fundamental problems of solar magnetic fields: their emergence and interaction in active regions to produce flares; their structure, evolution, and dissipation; their role in coronal

heating; and the nature of the solar cycle. The analysis of both the vector magnetograms and the UVSP spectroheliograms has been greatly facilitated by the color image processing developed by D. Rabin and E. Reichmann and reported last year.

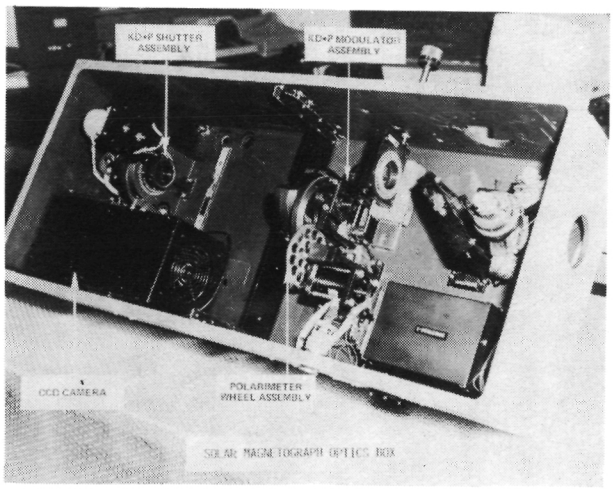

Figure 26. Solar Magnetograph Optics Box. Filtered light enters through the hole in the right-hand side, passes through the modulator, polarization analyzer, the shutter and into the CCD camera.

The relation between concentrations of vertical electric current and emission from the chromosphere-corona transition region in active regions is being investigated. In the first active region analyzed, the strongest observed current is not in the area of brightest UV emission; however, there are tantalizing hints of a general correspondence between stronger current and brighter emission, as shown in Figure 27. Therefore, if the lower transition region is heated mainly by electric current, the heating currents must be fine-scale and have no simple relation to the large-scale (approximately 5 arc sec) currents detectable with the vector magnetograph.

Motivated by this result, a theoretical study of the properties required of fine-scale currents if they are to heat the lower transition region shows that the current must be confined in filaments with diameters of a few meters. This dimension, though observably small, is large with respect to the relevant plasma parameters in the transition region; the current-carrying filaments in this picture would fill approximately 10^{-3} of the transition region volume.

The angle between the observed, transverse component of the magnetic field and the polarity inversion ("neutral") line in an active region is being investigated. An angle far from 90° is expected to indicate highly sheared field locations, places where the "free energy" of the magnetic field is high. In the first quantitative analysis, it is observed that the flares in an active region began just where the magnetic shear was highest, as inferred by this method from the observed transverse field.

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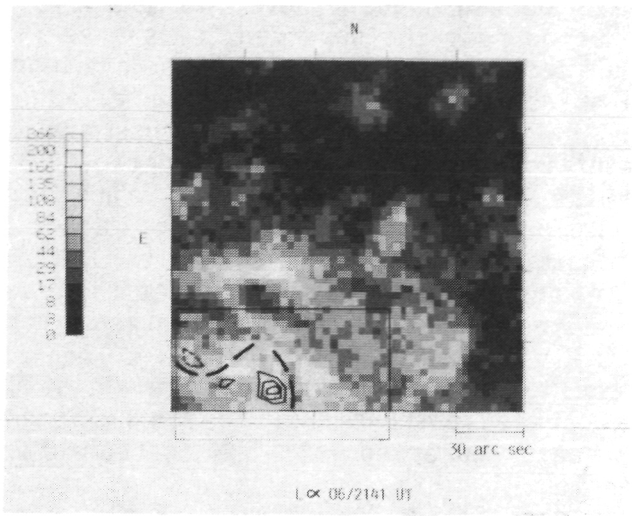

Figure 27. Vertical component of current density and Ly-alpha emission brightness. Contours of the vertical component of electric current density (at 06/1908 UT) are superposed on the Ly-alpha spectroheliogram for 06/2141 UT. The major current maximum is cospatial with a relatively weak but persistent Ly-alpha emission maximum in the small box which represents the overlap of the two instruments' field-of-view. The magnetic neutral line's location is shown by a heavy dashed line. Other (stronger) Ly-alpha emission maxima are not colocated with comparable current maxima. The weak enhancements visible in the upper part of the Ly-alpha image are elements of the chromospheric network seen in H-alpha.

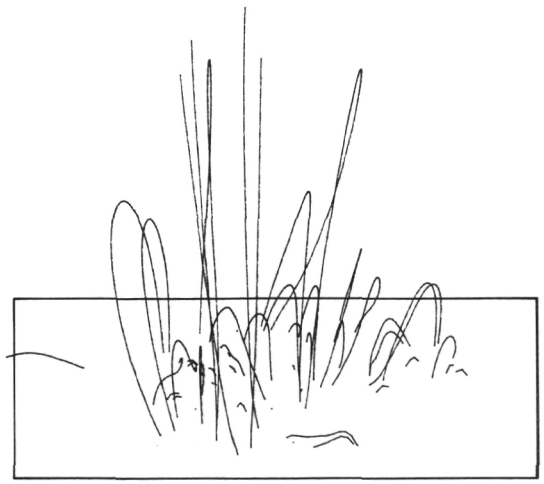

Figure 28. Force-free magnetic field lines for solar active region observed on September 23, 1980. For force-free parameter, alpha is uniformly equal to 0.0245 and the field is inferred from the observed vertical component of the field erupting through the surface. The calculated field lines for a family of values of alpha are compared with observed plasma structures to choose the value of alpha which best represents the physical

field is high. In the first quantitative analysis, it is observed that the flares in an active region began just where the magnetic shear was highest, as inferred by this method from the observed transverse field.

A study of MSFC vector magnetograms shows a clear example of flux disappearance within an active region by submergence. Submergence may be an important process in the evolution of flux balance in active regions, and hence, may be important for the global solar magnetic flux balance.

With members of the Arcetri Observatory, a study is underway to infer the three-dimensional morphology of the vector magnetic field above an active region and to compare it to the structures and processes occurring there, especially the observed cm-wave radio emission. Potential field calculations determine the magnitude and inclination of the magnetic field at coronal heights to determine if the observed radio emission can be ascribed to synchroton radiation from mildly relativistic electrons. In another study, with Lockheed astronomers, the three-dimensional field morphology of an active region observed with SMM instruments as well as with a Lockheed rocket experiment is inferred. Comparisons of calculated, uniform-alpha, force-free, magnetic fields (as shown in Figure 28) with Ly-alpha and H-alpha emission features are used to select appropriate values of the force-free parameter alpha. These alpha values are compared with those inferred from the observed magnetic field. (M. J. Hagyard and R. L. Moore/ ES52/205-453-0118)

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Hagyard, M. J., Teuber, D., West, E. A., Tandberg-Hanssen, E., Henze,Jr., W., Beckers, J. M., Bruner, M. Hyder, C. L. and Woodgate, B. E.: "Vertical Gradients of Sunspot Magnetic Fields," Solar Phys., 84, p. 13, 1983.

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Wu, S. T., Hu, Y. Q., Nakagawa, Y. and Tandberg-Hanssen, E.: "Induced Mass and Wave Motions in the Lower Solar Atmosphere. I. Effects of Shear Motion of Flux Tubes," Astrophys. J., 266, p. 866, 1983.

Statistical Solar Activity

The 22-year or "double" sunspot cycle has been examined using principal component analysis techniques. The first two eigenvectors (principal component) contain about 90 percent of the cumulative "signal power" and are

sufficient for good quality reconstruction of the sunspot cycle. The study provides additional evidence that the Sun behaves as a natural oscillator with a 22-year period.

A three-part study of the statistical aspects of the 1980 solar flares will be summarized in a single journal article. A more detailed study of the restricted period of January 1980, very near sunspot maximum for cycle 21, correlating flares, mass-ejection events, gradual-rise-fall radio events, Type II/IV radio events, and X-ray events has been completed. Two papers on sunspot cycles and long-term periodicities in the sunspot record show that values of selected parameters early in the cycle can be used to estimate the values of selected parameters occurring later in the cycle - in some cases several years later. On longer scales, based on smoothed sunspot numbers at sunspot maximum for cycles 8 through 20, it has been shown that an empirical function having a 2- and 11-cycle modulation of a 90-cycle sinusoid may be useful to give good estimates of smoothed sunspot maximum numbers for future cycles. For cycle 21, this function would have estimated (in advance) a value of 157.3, very close to the value actually observed. For cycle 22 the method's estimate of the cycle maximum sunspot number is much lower, about 107. (R. M. Wilson/ES52/205-453-2824)

Publication:

Wilson, R.: "Statistical Aspects of the 1980 Solar Flares - III. Parametric Comparison and Final Comments," NASA TM-82526, April 1983.

Infrared Telescope

Development continued on flight hardware for the Infrared Telescope (IRT) experiment scheduled for the Spacelab 2 mission in 1985. The IRT is a joint endeavor of the Smithsonian Astrophysical Observatory (SAO), the University of Arizona (UA), and MSFC. SAO is providing the Principal Investigator (G. Fazio), project management, and postflight data analysis; UA is responsible for the infrared optics; and MSFC provides the cryogenic system, mechanical equipment, and all integration and test functions. The University of Alabama in Huntsville has collaborated with MSFC in the development of the cryogenic apparatus. The Office of Space Science and Applications sponsors this development.

The infrared optics are carried in a helium gas-cooled, articulated cryostat which will scan about a single axis. Coupled with Orbiter motion, this will generate an extensive map of low-surface brightness and diffuse astronomical objects, and will produce data on the Orbiter/Spacelab induced environment and its effect on cryogenic infrared astronomy. Superfluid helium is stored in a 250-liter dewar which provides the cooling gas to the cryostat. Both the cryostat and dewar subsystems have been separately qualified.

The complete IRT assembly is now beginning its system acceptance tests. All components and functions will be operated; a long-term cryogenic servicing and performance test will be conducted; and finally, a thermal-vacuum test will be made. IRT is to be delivered to the Kennedy Space Center in January 1984 for integration into the Spacelab 2 system. (E. Urban/ES63/ 205-453-5132)

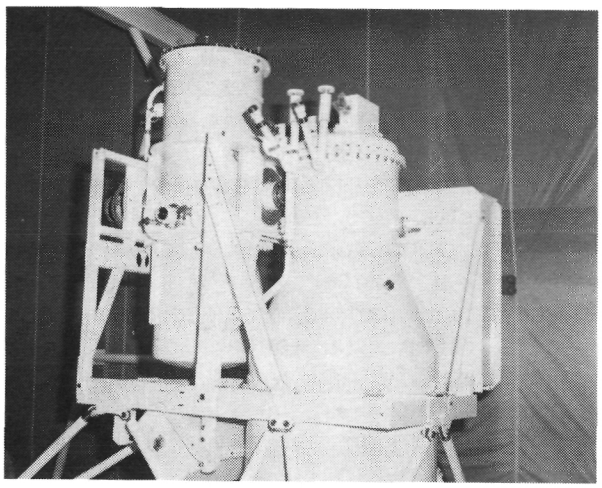


Figure 29. Partially Assembled IRT System.

Magnetospheric Physics

As the capabilities of plasma instrumentation have increased, a new focus on the Earth's space environment has emerged - that focus being the question of the origin of magnetospheric plasmas. Early space instrumentation was capable of only very high-energy (Mev) measurements with little or no composition information. The consequent observation of high-energy plasmas in the Earth's magnetosphere led to the immediate assumption that the Sun was the source of the plasma since the Earth's ionosphere was populated by gases of less than 1 eV in energy. As instruments developed and both lower energies and ionospheric-like composition signatures were found, the popular thought shifted from the Sun alone as a source of plasma to the currently perceived Sun-Earth combination as the source of Earth-space plasma.

Because the Earth's supply source is the ionosphere, the effective measurement of the energy, composition and dynamics of this plasma region, combined with the measurement of the transport of these plasmas up into the magnetosphere, became crucially important to the magnetospheric discipline. The bulk of the research activities of the Magnetospheric Physics Branch at MSFC is directed toward the study of low-energy plasma energization and transport. These studies involve the development of new instrumentation in the laboratory, its flight on sounding rockets, satellites, and the Space Shuttle, and the analysis of the resulting data through a computer networking approach. These R&T activities have laid the ground work for the successful development of instrumentation for projects [such as Spacecraft Charging at High Altitudes (SCATHA), Dynamics Explorer, Spacelab 1, and Spacelab 2], and are contributing significantly to the knowledge of the origin of magnetospheric plasmas. A more detailed treatment of some of the individual R&T activities and an indication of how they fit into the overall discipline of solar-terrestrial physics are listed in the following paragraphs. (C. R. Chappell/ES51/ 205-453-3036)

Retarding Ion Mass Spectrometer

Work continues on analyzing the measurements of the polar wind which was first measured by DE-1/RIMS at high altitudes in one of the early orbits of the mission. The current debate centers around whether the polar wind is subsonic or supersonic at high altitudes. Incomplete information on the potential of the DE-1 spacecraft makes this a difficult question to answer unambiguously. Evidence continues to mount that the polar wind is indeed supersonic particularly on field lines that open into the magnetotail.

In addition to the theoretically predicted H^+ and He^+ ion polar wind, RIMS has observed significant fluxes of O^+ ions flowing out of the polar cap during magnetically active conditions (Figure 30). These O^+ outflow events indicate a substantial change in the character of polar cap low-energy ion out-flow during disturbed conditions. The relative absence of H^+ ions during these O^+ events may indicate significant changes in the thermospheric density of atomic hydrogen over the polar cap during active conditions and may have significant implications for the supply of ionospheric H^+ and O^+ to the magnetosphere.

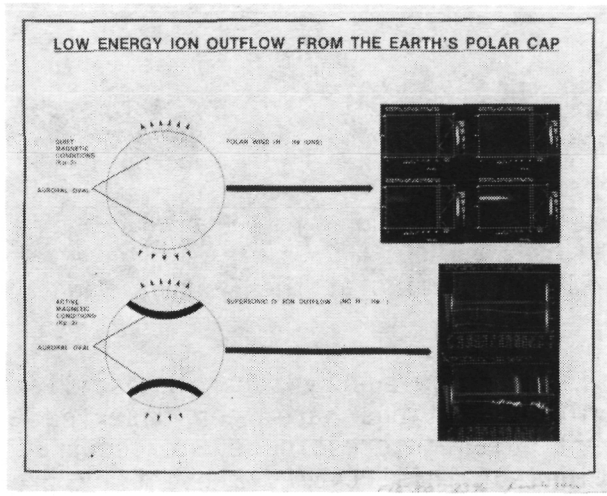


Figure 30. Low Energy Ion Outflow From the Earth's Polar Cap.

In addition to the low-energy polar ion outflows which generally have energies of less than 10 eV, RIMS has observed a new low-energy, field-aligned particle population with energies of tens of electron volts which has been given the name "auroral ion fountain" due to its existence at invariant latitudes which map downward to the auroral zone. These field-aligned ion beams which are composed of H^+, He^+, and O^+ ions appear to originate through acceleration processes in the topside auroral ionosphere. Subsequent convection of these ion flows toward the dayside results in a "warm plasmaspheric cloak" which surrounds the plasmasphere.

The polar cap and auroral ion streams were observed during the early phase of DE-1 mission (October-December 1981) when apogee was over the polar cap. When apogee precessed into the equatorial plane in the summer of 1982, the DE science team was treated to a totally new and equally interesting low-energy plasma environment. For the first time, a satellite obtained measurements for 2 or 3 hours as it traveled along a magnetic field line at

the outer edge of the plasmasphere (L 4.7). This unique orbital trajectory allowed repeated measurements of the effects of micropulsation events on the low-energy plasma motions and on the heating of the low-energy plasma near the Earth's magnetic equator. Perhaps one of the more interesting results to date is the apparent regularity with which equatorially trapped H^+ ions as measured by the RIMS and equatorial low-frequency intensification near 100 Hz as measured by the Plasma Wave Instrument (PWI) on DE-1 were simultaneously observed when crossing the magnetic equator near the plasmapause boundary (see Figure 31 for an example). Analysis of the data seems to indicate a heating of a significant fraction of the thermal H^+ plasma by particle-wave interactions.

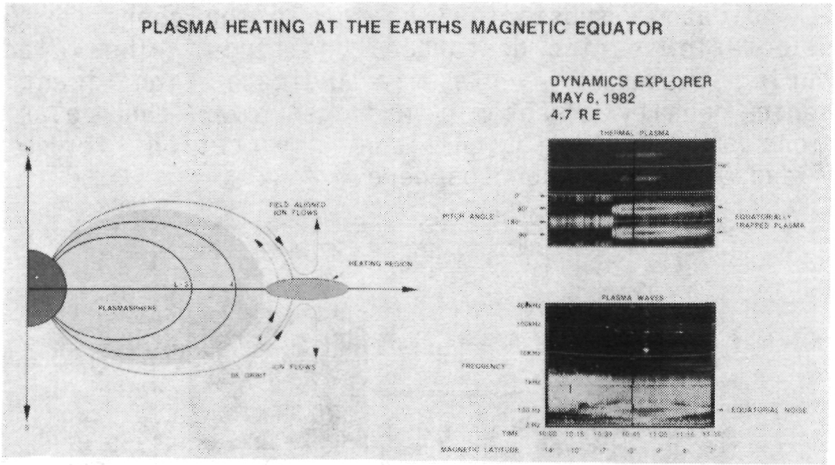


Figure 31. Plasma Heating at the Earth's Magnetic Equator.

Several observations of low-energy particle oscillations caused by E X B variations due to micropulsations have been observed at the edge of the plasmasphere. One particular interesting event occurred on July 14, 1982. Simultaneous observations of this PC-5/PC-2 event by ground-based magnetometers at Roberval and Siple and particle and wave instruments aboard the DE-1 spacecraft make this a particularly interesting event to study. RIMS observations clearly show a rotation of the thermal plasma in the plane perpendicular to the B field. The period of this rotation is the same as the PC-5 wave period observed by the three magnetometers. Work is still in progress to carry out a detailed comparison of the magnetic field, quasi-static electric field and low-energy particle measurements made by instruments on-board the DE-1 spacecraft.

In addition to these exciting new discoveries, data from RIMS has been used to increase our understanding of the morphology, density, temperature, and composition of the low-energy plasma torus that makes up the plasmasphere. Comparison of plasmapause and plasmasheet boundaries using the compliment of instruments aboard the DE-1 and DE-2 spacecrafts is progressing well and exciting new results concerning the post storm refilling of the outer plasmasphere by thermal plasma has just begun to yield significant new results (Figure 32). Several studies utilizing DE-1 magnetic conjunctions with ground-based incoherent radar facilities have also been carried out over the past year. These conjunctions studies are

reported separately in the section on Ionosphere/Plasmasphere Coordinated Measurements and Modeling. (H. Waite/ES53/205-453-3037)

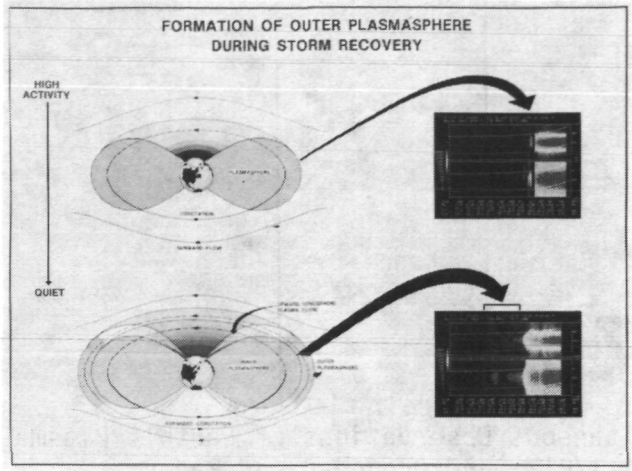


Figure 32. Formation of Outer Plasmasphere During Storm Recovery.

Ionosphere/Plasmasphere Modeling and Coordinated Measurements

A new program of computer modeling and coordinated observations of the ionosphere and plasmasphere of Earth has been initiated. The modeling has been used in conjunction with new, coordinated observations by the Retarding Ion Mass Spectrometer (RIMS) on Dynamics Explorer 1 and several ground-based incoherent scatter radar stations. Figures 33 and 34 represent a schematic overview of the types of coordinated observations which have been made. Included are a series of measurements during March 1983 using RIMS and the Arecibo Observatory radar. These measurements were made to measure the temperature and density structure of the low-latitude plasmasphere and to support observations at Arecibo using a new observational technique. Both data sets are undergoing analysis, and modeling is being carried out to aid in the interpretation of these results.

A series of observations involving RIMS and the Millstone Hill Observatory were performed in June 1983. The purpose was to study the time-dependent exchange of plasma between the ionosphere and plasmasphere. The observations included measurements of electron and ion concentration, temperature and flow velocity in the F region above Millstone Hill, and the measurement of ion temperature, density and flow velocity in the plasmasphere along the same magnetic field lines using RIMS. These data are being analyzed at present.

The RIMS instrument has also been used to support measurements by the Sondre Stromfjord radar in the polar cusp region. To this date there have been two cusp campaigns during which RIMS was operational. These studies are being performed primarily by Stanford University and the Sondre Stromfjord radar.

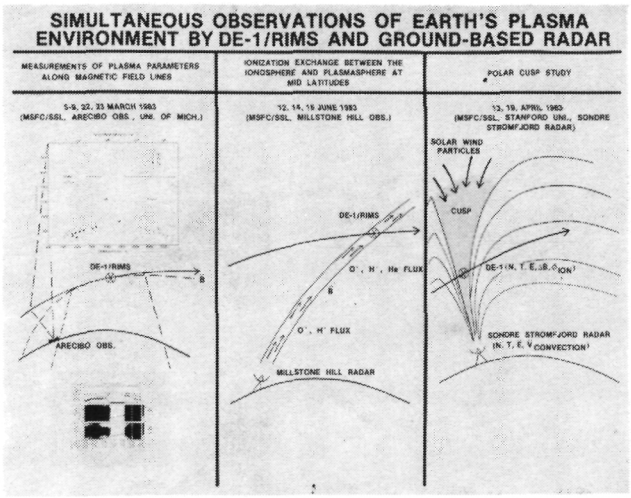


Figure 33. Simultaneous Observations of Earth's Plasma Environment by DE-1/RIMS and Ground-Based Radar.

DE-1, 2 AND CHATANIKA COINCIDENT OBSERVATION
OCTOBER 26, 1981 NEAR 20 HRS. MLT

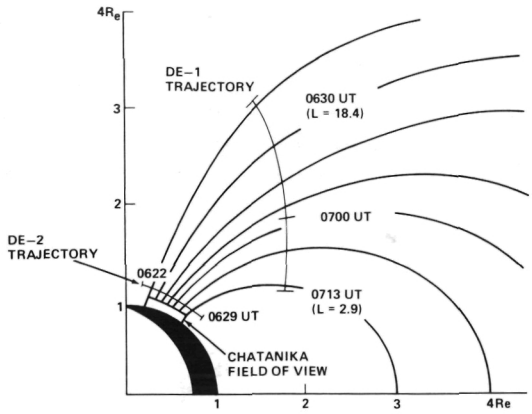


Figure 34. DE-1, 2 and Chatanika Coincident Observation.

In a separate ongoing coincidence study, data from simultaneous observations of high-latitude magnetic field lines by instruments on the DE-1 and DE-1 spacecraft and the Chatanika radar have been compared using the Space plasma Computer Analysis Network (SCAN) network facilities, and a coordinated study has begun involving many scientists from the DE project and the Chatanika facility. The study is focusing on the identification of plasma boundaries at high latitudes and the way these boundaries map along field lines from the F region upward into the plasmasphere and magnetosphere. The dynamics and energetics of the ions in these regions are also being studied. Computer modeling of this region is being performed in conjunction with this study to aid in theoretically understanding the exchange and energization of plasma between the ionosphere and inner magnetosphere. (H. Waite/M. Chandler/ES53/205-453-3037)

Publications:

Chandler, M., Waite, J. H., Chappell, C. R., Behnke, R. A., Gonzales, C. A. and Nagy, T.: "Simultaneous Observations of the Low-Latitude Ionosphere by the Dynamics Explorer Retarding Ion Mass Spectrometer and the Arecibo Observatory," J. Geo. Res. (to be submitted).

Green, J. L., Waite, Jr., J. H., Chandler, M., Chappell, C. R., Comfort, R. H., Doupnik, J. R., Foster, J., Heelis, R. and Shawhan, S. D.: "High Latitude Plasmapause Observations," Abstract for the UAH/MSFC Plasmapause Conference to be held in Huntsville, Alabama in October 1983.

MSFC/SCAN System

The MSFC SCAN (Space plasma Computer Analysis Network) system is being integrated into the newly designed central computers of the Data System Technology Program (DSTP) here at MSFC. The SCAN network links several remote users to the DSTP computers in building 4487. At this time, the network is configured so that there are nine "remote" (not at the central site) nodes in the network: University of Texas at Dallas, Utah State University, Stanford University, University of Iowa, Los Alamos National Laboratory, Goddard Space Flight Center, Space Science Laboratory (MSFC), and two new nodes added this fiscal year (University of Michigan and Southwest Research Institute). Each of the remote nodes has a direct line into the DSTP system. The SCAN system was initially devised to test the capabilities and help to demonstrate the new technology being developed by the DSTP. However, SCAN/DSTP's importance within the scientific community as an analysis tool has now become far greater than was originally anticipated.

The SCAN network provides remote nodes with access to growing space science data bases and brings scientists throughout the country together in a common working environment. A typical data analysis laboratory such as the Magnetospheric Physics Branch at MSFC resides at each node. Users at their institutions participate in a number of network functions involving the central DSTP computer facilities and other remote computer capabilities. Data and graphics files can be transferred to and from the DSTP and other remote facilities. Program execution can be initiated from any of the network nodes (distributive processing). The DSTP computer facility has a growing library of analysis software that can be transferred to remote nodes or executed at the central site. For example, the user at a remote site can initiate a library program at the central site which reads and analyzes data out of the mass memory assembly (currently a disk system) and then have the results transferred to his node. All of the nodes have the capability for message routing, enabling the remote nodes to communicate to each other as if a direct phone line existed between them, even though they may not be "adjacent" nodes.

A NASA advisory working group was formed, called the Data System Users Working Group (DSUWG), which oversees all activity on SCAN and provides direction for SCAN growth. It has been recognized by the DSUWG that computer networking provides the best available means of meeting collaborative scientific requirements in the most efficient and cost effective manner for archived, current and future data bases. The DSUWG recommended that NASA establish a solar and space physics pilot program to create a Space Physics

Analysis Network (SPAN) that would link together a large number of NASA space scientists. In addition, the DSUWG stated that SPAN should use as its foundation the current SCAN system (based at MSFC) and that MSFC should be identified as the lead NASA field center in the pilot program, based upon present extensive efforts of SCAN It is anticipated that SPAN will grow extensively in the next fiscal year and that it will become a fundamental tool for space plasma research. (J. Green/ES53/205-453-0028)

Publications:

Banks, P. M., Williamson, P. R. and Raitt, W. J.: "Space Shuttle Glow Observations," Geo. Res. Lett., 10, p. 118, 1983.

Chappel, C. R.: "Cold Plasma Distribution Above a Few Thousand Kilometers at High Latitudes," in High-Latitude Space Plasma Physics, edited by Bengt Hultqvist and Tor Hagfors, Plenum Publishing Corporation, 1983.

Green, J. L.: "The Io Decametric Emission Cone," Radio Science, (accepted).

Green, J. L., Waite, J. H., Johson, J. F. E., Doupnik, J. R. and Heelis, R.: "MSFC SCAN Network Stage 1 Workshop," NASA TM-82514, April 1983.

Mende, S. B., Garriott, O. K. and Banks, P.M.: "Observations of Optical Emissions on STS-4," Geo. Res. Lett., 10, p. 122, 1983.

Gravitational Physics

Superconductivity and Thin Film Research

Advanced research and development have continued toward meeting the requirements for the Gravity Probe-B (GP-B) experiment proposed by Stanford University. Having obtained reproducibility in producing macroscopically uniform superconducting films on gyro rotors, attention was concentrated on eliminating penetrating pinholes produced when dust particles are overcoated. While removing all dust particles from rotors prior to coating is extremely difficult, standard techniques of shifting particle positions between multiple coatings were improved so that pinholes do not completely penetrate the films. Rotors produced with sufficiently thin films to assure that mass balancing requirements were met have been suspended under full gravitational (1 g) weight at Stanford University.

Having produced satisfactory prototype readout circuits using the exposure of photoresists with a focused point source, the technology using contact printing of mask patterns produced with the point source technique was improved. Since the circuit area is large (in excess of 4 cm diameter) and the circuit lines small (less than 20 m wide), good contact between the gyro housing halves and the mask is more difficult to accomplish than is usually the case. Both masks on optically flat surfaces and conformal masks have been investigated. The final technology circuit fabrication should be considerably faster and easier to transfer to contractors or others who may be required to produce GP-B readout circuits.

Several areas of application of thin films to infrared research for astronomical applications have been investigated. The use of normal metal thin film circuits, as well as superconducting circuits, for arrayed sensors has been examined, and improvements in fabrication techniques and device characteristics are predicted. (P. Peters/ES63/205-453-5134 and R. Sisk/ES63/205-453-5137)

Astronomy

X-Ray Astronomy

The research program in X-ray astronomy is divided into three areas: analysis and interpretation of data from the Time Interval Processor of the Monitor Proportional Counter that flew onboard the HEAO-2 Observatory; the laboratory development of an advanced X-ray polarimeter; and the Advanced X-Ray Astrophysics Facility (AXAF) technology program. Several extremely interesting objects were observed with the HEAO-2 which have led to many publications in the refereed literature this year. One observation of particular interest compared the time variability and spectroscopy of two of the leading black hole candidates, Cygnus X-1 and LMC X-3. These two objects appeared to be totally dissimilar, thus calling into question just what is the X-ray signature of a black hole.

Work on the development of the X-ray polarimeter has continued. A new detector was recently delivered, and tests have begun. Significant accomplishments were also achieved in support of AXAF. Specifically, all the results of the detailed measurements of X-ray scattering from a variety of test samples are being compiled into a NASA Technical Memorandum. This work was primarily accomplished utilizing the MSFC X-Ray Calibration Facility and involved personnel from the Test Laboratory and the Optical Systems Branch of the Information and Electronics Systems Laboratory. This research is sponsored by the Office of Space Science and Applications. (M. Weisskopf/ES62/205 453-5133)

Publications:

Leahy, D. A., Darbro, W., Elsner, R. F., Weisskopf, M. C., Sutherland, P. G., Kahn, S. and Grindlay, J. E.: "On Searches for Pulsed Emission with Application to Four Globular Cluster X-Ray Sources: NGC 1851, 6441, 6624, and 6712," Astro. J., 266, pp. 160-170, 1983.

Elsner, R. F., Darbro, W., Leahy, D., Weisskopf, M. C., Sutherland, P. G., Kahn, S. M., and Grindlay, J. E.: "X-Ray Observations of 4U1626-67 by the Monitor Counter on the Einstein (HEAO-2) Observatory," Astro. J., 266, pp. 769-775, 1982.

Darbro, W. A. and von Tiesenhausen, G.: "Sequences Generated by Self-Replicating Systems," Fibonacci Quarterly, 21, p. 97, 1983.

Williams, A. C.: "Hamilton-Jacobi Expansion of the Scattering Amplitude," Inter. J. Theor. Phys., 22, p. 219, 1983.

Weisskopf, M. C., Elsner, R. F., Darbro, W., Leahy, D., Naranan, S., Sutherland, P. G., Grindlay, J. E., Harnden,Jr., F. R. and Seward, F. D.: "The Period History of the X-Ray Pulsar in MSH 15-52," Astro. J., 267, pp. 711-712, 1982.

Singh, K. P., Agrowal, P. C., Manchanda, R. K., Naranan, S., and Sreckantan, B. V.: "Spatial Distribution and Spectral characteristics of the Diffuse Soft Soft X-Ray Background," Astrophys. J., 117, p. 319, 1983.

Leahy, D. A., Elsner, R. F. and Weisskopf, M. C.: "On Searches for Periodic Pulsed Emission: The Rayleigh Test Compared to Epoch Folding," Astro. J. (in press).

Williams, A. C., Elsner, R. F., Weisskopf, M. C., and Darbro, W.: "Photon Escape Probabilities in a Semi-Infinite Plane Parallel Medium. Astrophys. J. (in press).

Gamma-Ray Astronomy

Research in gamma-ray astronomy at MSFC has been primarily directed toward observations of transient and periodic high-energy sources. Analysis of data from high-altitude balloon flights in 1980 and 1982 continued to provide new information on these sources. The balloon-borne detector array (Figure 35) uses large-area scintillation detectors developed by the MSFC group. Onboard data processing system preprocesses large amounts of data prior to transmission to ground stations. In addition to providing new astrophysical data, the balloon flight experiments contribute to the development of the Burst and Transient Source Experiment (BATSE) for the Gamma-Ray Observatory (GRO) and to the development of future detectors and observational techniques for gamma-ray astronomy.

Observations of the pulse profile from the pulsar in the Crab Nebula were made with greater accuracy than those previously made in the energy range above 45 keV. Time variability of the profile is also being analyzed. These observations provide data for models of the high-energy emission from rapidly rotating neutron stars.

A new observation of the rate of weak gamma-ray bursts was made, using data from the 1980 and 1982 balloon flights. This measurement is important for the determination of the distance scale and luminosity of the burst sources. The basic nature of these enigmatic objects is still unknown; a determination of the luminosity is vital to distinguish between possible models. (G. Fishman/ES62/205-453-0117)

Publications:

Wilson, R. B., Fishman, G. J. and Meegan, C. A.: "Observations of a Gamma-Ray Burst and Other Sources with a Large-Area, Balloon-Borne Detector," AIP Conference Proceedings, 77, pp. 67-78, 1982.

Fishman, G. J., Meegan, C. A., Parnell, T. A. and Wilson, R. B.: "The Burst and Transient Source Experiment for the Gamma-Ray Observatory," AIP Conference Proceedings, 77, pp. 443-451, 1982.

Wilson, R. B. and Fishman, G. J.: "The Pulse Profile of the Crab Pulsar in the Energy Range 45 keV-1.2 MeV," Astrophys. J., 269, pp. 273-280, 1983.

Figure 35. The Gamma-Ray Astronomy Experiment after its descent by parachute onto the desert near Winslow, Arizona, on May 31, 1982. The flight was launched from Greenville, South Carolina, two days before. Data were gathered at an altitude of 40 km and transmitted to four ground stations along the flight path.

The Marshall Mid-Infrared Array Camera

MSFC is currently developing a camera detector system for astronomical observations in the wavelength range 5-30 m. Although the highly sensitive camera system is applicable to a broad range of programs, its primary purpose will be to obtain infrared maps of star formation regions in the Milky Way and other galaxies and to investigate sources discovered by the Infrared Astronomical Satellite (IRAS). During astronomical observations, the telescope focal plane will be re-imaged onto the camera's square array of 20 field mirrors arranged in 4 columns and 5 rows. Each field mirror will provide a pixel size of approximately 5 arc seconds when used at the 3-meter Infrared Telescope Facility (IRTF) telescope in Hawaii, with a corresponding total array size of 20 x 25 square arc seconds. The radiation incident on each field mirror will be focused onto a square bolometer detector chip 0.3 mm in size. To achieve high sensitivity, the bolometers and camera optics must be cooled to 1.4 K using liquid helium. Most of the essential long lead-time camera components, such as the detectors and associated electronics, have been ordered or are under construction. Field tests will begin in February 1984. (C. Telseco/ES63/205/453-5134)

MATERIALS PROCESSING IN SPACE

Introduction

Because of the high cost of space experimentation and the limited flight opportunities available, it is imperative that candidate processes for space experimentation be thoroughly understood before the experiment is flown. This requires extensive modeling of the process, measurements of many thermophysical properties, and, in many cases, use of precursory experiments in which gravitational effects are minimized by use of neutral density analogs, use of viscous fluids and small flow geometries, use of magnetic fluid damping, etc., or temporarily suspended by use of drop facilities or aircraft flying ballistic trajectories.

The MPS program is presently sponsoring some 90 investigations at a number of universities, private corporations, and government laboratories. The total program is summarized in NASA TM-82525, "Materials Processing in Space Program Tasks," published by MSFC. The results reported in this document are from investigations that have been supported by the MPS program at MSFC over the past several years and are representative of the work being accomplished in the program. (R. Naumann/ES71/205-453-0940)

Crystal Growth and Characterization

Accurate thermal models of space crystal growth are required for developing space-borne experiments of these phenomena. Such models require accurate thermophysical properties which, for compounds such a HgCdTe, are difficult to measure because of the high vapor pressure. Novel methods were developed at MSFC for making density and thermal diffusivity measurements of this material at the temperatures encountered in crystal growth from the melt. Two important results were discovered: (1) $Hg_{1-x}Cd_xTe$ (which expands when it freezes) has a liquid-phase density inversion for $x \leq 0.2$, and (2) a sharp increase in thermal diffusivity is noted as the crystal melts, indicating a semiconductor to metal transition. This has important significance to crystal growth of this material, and possibly to other important semiconductor materials. The liquid-phase density inversion may be the source of yet another gravity-driven convective instability that could affect the homogeneity of this system. Since many II-IV and III-V compounds expand when they freeze (as well as Si and Ge), liquid-phase density inversions may be present in other systems. The sharp increase in thermal diffusivity in the melt can produce severe distortions in the shape of the solidification isotherms especially if the growth ampoule carries a substantial portion of the heat. It has been shown that the conventional practice of using an adiabatic zone in Bridgman growth to flatten the isotherms in the growth region may have the opposite effect in such systems. (S. Lehoczky/ES72/ 205-453-3090)

Publications:

Kelley, J. D., Martin. B. G., Szofran, F. R. and Lehoczky, S. L.: "Application of the Regular Associated solution Model to the Cd-Te and Hg-Te Binary Solutions," J. of the Electrochemical Soc., 129, p. 2360, 1982.

Naumann, R. J. and Lehoczky, S. L.: "Effect of Variable Thermal Conductivity on Isotherms in Bridgman Growth," J. of Crystal Growth, 61, pp. 707-710, 1983.

Szofran, F. R. and Lehoczky, S. L.: "Liquidus Temperature of Hg-Rich Hg-Cd-Te Alloys," J. of Electronic Materials, 12, p. 713, 1983.

Holland, L. R., Harris, R. P. and Smith, R.: "High Temperature, High Pressure, Optical Cells," Review of Scientific Instruments, 54, p. 993, 1983.

Holland, L. R. and Taylor, R. E.: "Measured Thermal Diffusivity of HgCdTe Solids and Melts," J. of Vacuum Science and Tech., A1, p. 1615, 1983.

Chandra, D. and Holland, L. R.: "Density of Liquid HgCdTe," J. of Vacuum Science and Tech., A1, p. 1629, 1983.

Model Immiscible Systems

Substantial progress has been made in the observation and measurement of nucleation, growth, and ripening phenomena of second phase liquid droplets using holographic microscopy techniques. A holographic microscopy technique developed by Witherow at MSFC has been used to observe the growth and ripening of second phase succinonitrile liquid droplets nucleating in a monotectic system (succino-nitrile-H_2O) as it is cooled into the twoliquid phase region. By using a carefully thermostated system, a neutral density point was maintained so that growth and ripening could be studied in the absence of Stokes settling. Holograms taken at periodic intervals recorded the total droplet field. These can later be reconstructed, and individual droplets may be examined microscopically. Automated counting and sizing techniques have also been developed to obtain size distributions. Sizes can be determined accurately down to 3 microns with the present system.

The holographic system used by Witherow is compatible with the holographic system on the Fluids Experiment System (FES). We see some exciting applications for this system in performing critical tests of nucleation and ripening theories. To this end, classical theories of homogeneous nucleation have been reviewed, and a modified theory has been developed by Rasmussen (Clarkson University). An extensive review of the classical Lifshitz-Slyzov-Wagner (LSW) theory for Ostwald ripening has been completed by Baird (University of Alabama-Huntsville) to determine what predicted phenomena would provide a critical test. Meanwhile Glicksman (Rensselaer Polytechnic Institute) is developing an improved theory of Ostwald ripening that could possibly be tested. The holographic system will allow nucleation and associated phenomena to be observed in progress and analyzed, providing information previously not obtainable. This experimental data should allow the development of a complete understanding of the processes involved. This basic information should have widespread application to any solification process. (D. Frazier/ES74/205-453-3090)

Electrophoresis

The electrical conductivity of the sample and the buffer solution must be carefully matched to fully utilize the high sample concentration possible in low gravity. Otherwise, electric field distortions near the buffer cause an increased bandspread and reduced resolution, thus compromising the advantages of low gravity operations. It has been shown that dramatic increases in throughput can be realized in Continuous Flow Electrophoresis (CFE) performed in low-gravity by increasing the flow channel width and the concentration of the sample stream. This is highly significant for McDonnell Douglas Aircraft Corporation (MDAC) which is developing a space CFE device for commercial use, since this is the major advantage of low-gravity operation that it has identified. From a scientific point of view, the sample runs for NASA as part of the Joint Endeavor Agreement, revealed some interesting insight on the effect of conductivity mismatch between the sample stream and the buffer. The high sample concentration attainable only in low-gravity allows considerably more mismatch between the electrical conductivity than is usually experienced on the ground. This causes a distortion in the electrical field in the vicinity of the buffer which causes the sample to migrate toward the walls. (R. Snyder/ES73/205-453-3537)

Omenyi, S. N. and Snyder, R. S.: "Vertical Ascending Electrophoresis of Cells with a Minimal Stabilizing Medium," Preparative Biochemistry (in press).

Omenyi, S. N. And Synder, R. S.: "Settling of Fixed Erythrocyte Suspension Droplets," Biorheology, 20, pp. 109-118, 1983.

Growth of Precision Latex Spheres in Low-Gravity

The scientific community requires uniformly sized particles in the micron range for calibration purposes. This experiment's goal is to produce such particles. The first phase of Dr. Vanderhoff's (Lehigh University) monodisperse latex reactor experiment was completed on STS-7. This series of four flights used a seeded polymerization technique to grow latex spheres to sizes in the range of 5-20 microns in low-gravity. The principal advantage of low-gravity is the ability to keep the particles in suspension without having to add excessive emulsifier, which initiates a new crop of particles, or rapid stirring which can result in shear-induced flocculation. The space-produced particles were superior to those produced by ground-based techniques in both sphericity and size uniformity according to an independent analysis by the National Bureau of Standards (NBS). NBS has requested additional space-produced particles for use as calibration standards. Dale Kornfeld, MSFC, was Co-Investigator on this experiment. (D. Kornfield/ES73/205-453-0185)

Publication:

Vanderhoff, J. W., El Aasser, M. S., Micale, F. J., Sudol, E. D., Tseng, C. M., Silanowicz, A., Kornfeld, D. M. and Vicente, F. H.: "Preparation of Large Particle Size Monodisperse Latexes in Space: Polymerization Kinetics and Process Development," AICHE Spring National meeting, March 1983.

SPACE POWER

Low Concentration Ratio Solar Array

Experimental and analytical evaluation of a truncated pyramidal concentrator solar array has been underway for several years and was completed in FY-83. This approach is illustrated in Figure 36. As indicated in this figure, each concentrator element folds flat and strings of them deploy to produce a solar array wing. In the baseline design, the concentrator was half a meter in length on each top edge. A complete design of the solar array wing, including necessary drawings, was produced. The analysis, such as structural, thermal, dynamic and material, required to produce such a design was performed. Test hardware was fabricated and tested to verify performance predictions.

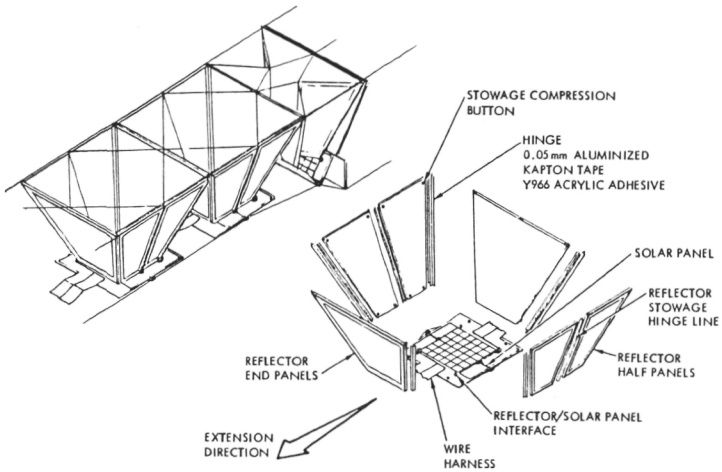


Figure 36. Illustration of Low Concentration Ratio Solar Array.

A concentrator design requires fewer solar cells, the most expensive solar array components. Also, the more efficient GaAs solar cells allows a reduction in solar array size for the same power output as with conventional arrays. This work was conducted in conjunction with Rockwell International. Mr. S. J. Nalbandian was the project manager at Rockwell. (M. Carruth/ EB12/205-453-4275)

Publications:

Nalbandian, S. J. and French, E. P. (primary authors) and et al: Low Concentration-Ratio Solar Array for Low Earth Multi-100 kW Applications; Vol. I and II, Final Report - July 1983, Rockwell Report SSD 83-0075-1 and -2.

French, Edward P., Mills, Michael W. and Bakovsky, Zdenek: Optical Thermal and Electrical Performance of Low CR Solar Arrays, 18th IECEC, August, 1983.

Biss, Mike S. and Hsu, Lau: Mechanical Design of Low CR Solar Array for Space Station Application, 18th IECEC, August 1983.

Space Power Miniature Cassegrainian Concentrator Solar Array

The miniature cassegrainian concentrator solar array development has been pursued for several years. Experimental and analytical evaluation have so far indicated that this solar array shows significant promise for reducing solar array cost and size. Each individual concentrator, a number of which are shown mounted in a panel in Figure 37, has a concentration ratio of near 100. The configuration is such that the concentrator elements are required to point to the sun with a pointing accuracy of + 2 degrees. The solar array design must, therefore, be such that this pointing accuracy is maintained across the array to prevent power degradation. TRW's Space and Technology Group recently completed a study, directed by Mr. Robert Patterson, for the Marshall Space Flight Center to evaluate the capability to maintain the required pointing accuracy. A preliminary design of a 100 kW solar array was produced and analyzed relative to structural and thermal stability, dynamic response to various force inputs and manufacturability. The results indicate that the anticipated angular variation across the solar array is 1.3 degrees and, therefore, within an acceptable range. (L. Crabtree/EB12/205-453-4642)

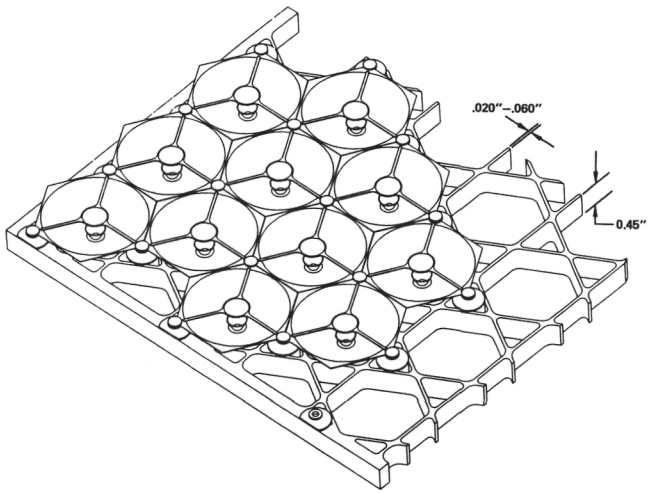


Figure 37. Space Power Miniature Cassegrainian Solar Array Panel.

Publications:

Patterson, R. E.: Study of Multi-Kilowatt Solar Arrays for Earth Orbit Applications, Final Report, August 1983, TRW Report No. 38172-6001-UE-00.

Patterson, R. E.: Preliminary Concept of a 100 kW Cassegrainian Concentrator Solar Array, Sixth Space Photovoltaic Research and Technology Meeting, October 1983.

Participating Companies/Universities: TRW and Technology Group, Redondo Beach, CA.

MATERIALS

Determination of Hydrogen Concentrations in Metals

The importance of hydrogen-induced failure of materials has been widely recognized. Catastrophic failure of high strength steel parts, such as aircraft landing gears, is often attributed to hydrogen embrittlement. The source of hydrogen causing failure in the presence of stress can be a corrosion reaction but can also be a pretreatment process such as a pickling, a welding, or a plating process. Thus, there is widespread interest in developing methods for the determination of hydrogen concentrations which are fairly low, in many cases, in metallic structures. A device, termed the "barnacle electrode," for determining the hydrogen concentration in steels has been developed and evaluated which is based on the electrochemical permeation technique. The device has met with a great deal of success. It was the purpose of the present work to develop a similar electrochemical technique for the measurement of hydrogen using the Model 350A Corrosion Measurement System and to present a series of results concerning hydrogen uptake, elimination by baking, uptake during electroplating, and the effect of heat treatment for high strength steels.

The results of this study indicate that the Model 350A Corrosion Measurement System can be used successfully to determine small hydrogen concentrations. While it is desirable to verify these measurements with hydrogen extraction or vacuum fusion techniques, the concentrations of hydrogen are generally too low for accurate measurements using these methods. The results indicate that hydrogen uptake is not linear with time of electrolysis, but rather asymptotically approaches a saturation level with time. The results also indicate that some of the hydrogen diffuses into the metal. Although exceptions occur, agreement is found generally between hydrogen retention times during hydrogen elimination by baking and the tendency toward hydrogen embrittlement. Also, the effect of heat treating high strength steels is to increase hydrogen retention times. Hydrogen uptake during electroplating, using bright Cd and dull Cd plating solutions, is not as great as expected, although the results of this study indicate that hydrogen uptake in the dull Cd case is greater than that in the bright Cd case. This would be in agreement with the fact that dull Cd plating is more hydrogen embrittling than bright Cd plating. (M. Danford/EH24/205-453-5872)

Publication:

Danford, Merlin D.: "An Electrochemical Method for Determining Hydrogen Concentrations in Metals and Some Applications," NASA Technical Paper 2113, January 1983.

Chromium Ion Plated 440C Steel for Turbopump Bearings

Ion plating is a relatively new technique of surface treatment that has shown potential for bearing applications. In this technique, metal ions are accelerated in an electric field and deposited on the surface to be plated. Prior to deposition, the surface is cleaned by the sputtering action of argon plasma generated in the process. The combination of atomically clean surface and high speed of depositing ions produces strongly adherent coatings. The ion plated species penetrates the surface a few atom layers and a good bond between the coating and the substrate is produced. (B. Bhat/EH23/205-453-5509)

The Effects of Processing Parameters on Structure and Properties of MAR-M-246

A two-year program to study the structure of MAR-M-246 (Hf), an SSME turbine blade alloy, has recently been completed. It included a study of the solidification process and the heat treatment.

Numerous samples were directionally solidified in a platinum-wound furnace with a copper cooled quench block. Growth rates varied from one cm/hr to 42 cm/hr. The secondary dendrite arm spacings were shown to decrease linearly with growth rate, and the carbide shapes varied from blocky at the slow rates to script-like at the fast rate. The arm spacings were also found to vary with deviation from [001], decreasing as the deviation increased. But the volume fraction of carbides present increased as the secondary arm spacings increased, indicating that deviation from [001] during growth might not have a detrimental effect on the microstructure of the alloy if it served to diminish the number of carbides.

A series of heat treatment studies was made to ascertain the minimum heat treatment that would produce desirable structure. The γ' strenghtening phase appeared to go into solid solution between 1175 and 1200°C. The alloy can therefore be solution treated as low as 1200°C and avoid the risks, such as incipient melting, that can occur at higher temperatures. When precipitating the γ' in a controlled fashion, it reaches a maximum volume percent at around 100 hours of heat treatment at 871°C and 982°C. But in the case of 982°C, the size is not stable since the γ' continues to increase in size. Therefore, the material can be stabilized (ωrt γ') at the 871°C temperature, but will be unstable if it sees any higher temperature. The structure would become unstable and the alloy would decrease in strength.

Mechanical fatigue tests on single crystal samples were done on groups with orientations ranging from 0° to 15° deviation from [001]. The fatigue properties decreased at the 15° orientations. X-ray analysis of the samples indicated that the secondary orientation (e.g., the deviation from [001] was equally significant since it is the availability of slip systems which determines the lifetime to failure. Samples which are oriented for easy slip (near [111] and [001]), fail less rapidly than those which have difficulty finding a slip system. Crystals should therefore be oriented within 10° of the [001] and toward the [001] - [011] boundary in order to obtain the strength advantages of this orientation.) (M. Johnston/EH22/205-453-5510)

Thermomechanical properties (glass transition and expansion coefficient) and thermogravimetric properties were determined. It is expected that this new class of urethane materials will have application in Shuttle GSE hardware where a combination of oxidative and moisture resistance is critical (D. Morris/EH33/ 205-453-1231)

Improved Protective Cover/Light Block for Multilayer Insulation (MLI)

This task was directed toward demonstrating the feasibility of using a scrim-reinforced, single metallized, 4 mil Tedlar film as a replacement for the Teflon coated Beta-cloth/single metallized 3 mil Kapton film presently used as the protective cover/light block for multilayer insulation (MLI) on the Orbiter, Spacelab and other space applications. The proposed Tedlar concept will be lighter and the cost potentially lower. Thermal analysis with the proposed concept was much simpler than with the present system. Tests have already demonstrated that white Tedlar has low alpha (absorption) degradation in space from U.V. This study indicated the the proposed concept was significantly less expensive with nominal weight savings of 50%. Plans are currently underway to incorporate this concept in flight hardware. (L. Thompson/EH33/205-453-1231)

Labyrinth Seals for Incompressible Fluids

This effort was intended to develop and improve criteria for the design of labyrinth seals for use in incompressible fluids. This in turn would reduce the parasitic flows inherent in pump designs, thereby resulting in pump efficiency improvement and/or reduction in turbine inlet temperature requirement.

Typical Space Shuttle Main Engine (SSME) labyrinth seal design configurations were used as baseline for the test seal design. Typical seals tested were stepped, straight-through, combination stepped and straight, rectangular cavity, and contour cavity configurations. Tests were conducted using water at room temperature. Figures 38 through 41 show schematic representations of the test section, and the test seals.

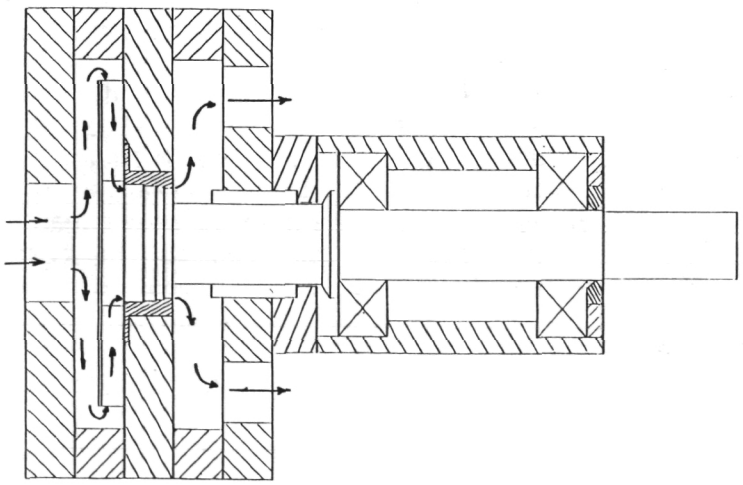
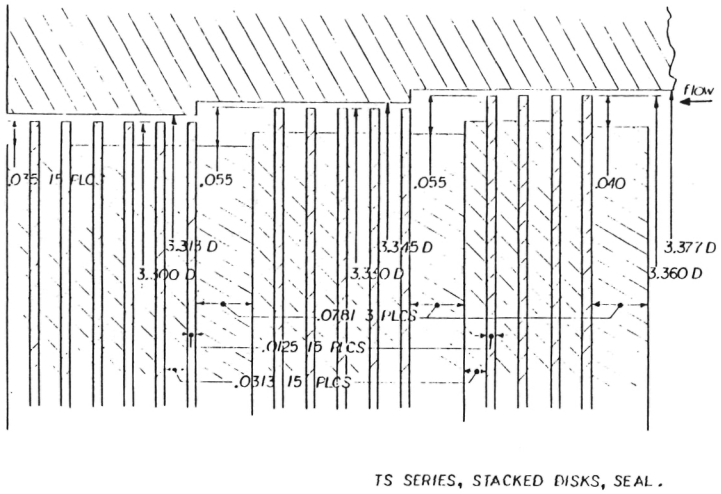


Figure 38. Schematic of Labyrinth Seal Test Section.

This investigation also included a survey of existing prediction techniques for leakage through labyrinth seals. These methods have been summarized and documented in an interim report. The various empirical techniques found in the literature survey were analyzed for accuracy with respect to the experimental results from the labyrinth seal configurations tested. It was determined that the prediction method developed by L. Dodge produced results relatively close to the test data. It was also found that by slight modification of Dodge's leakage formula, a more accurate solution is produced.



TS SERIES, STACKED DISKS, SEAL.

Figure 39. Schematic of Straight-Through Labyrinth Seal with Rectangular Cavity Contours.

Generalized prediction techniques were subsequently developed for both straight-through and stepped seals making use of the modified Dodge's formula to determine an initial flow coefficient and then applying corrections for clearance to pitch ratio, tooth width, tooth height, pressure ratio, shaft speed and number of teeth of the particular seal under consideration using the test data obtained from the literature survey and the tests conducted in this investigation. The equation for carry-over coefficient proposed by Hodkinson is used since data reported by previous investigators like Eglic, Hodkinson, Komotoric and Mori and Jerie fit closely to the equation. A computer program using a prescribed method for calculating the flow coefficient and mass leakage rate has been written using Fortran IV operating under a CP/M-80 operating system. The program performs all the necessary interpolation, extrapolation and normalization of the graphical data which is stored in array form in the computer program. Results from this leakage prediction technique, when compared to the test data obtained from this investigation, were determined to be in good agreement through the pressure ratio range.

This program is now nearing completion. the final report is currently being preparation for publication. (F. Garcia/EP23/205-453-3812)

Publication:

Cogan, K. C.: "Leakage Prediction of Incompressible Fluids in Labyrinth Seals," thesis submitted to the Graduate College of Texam A&M University in

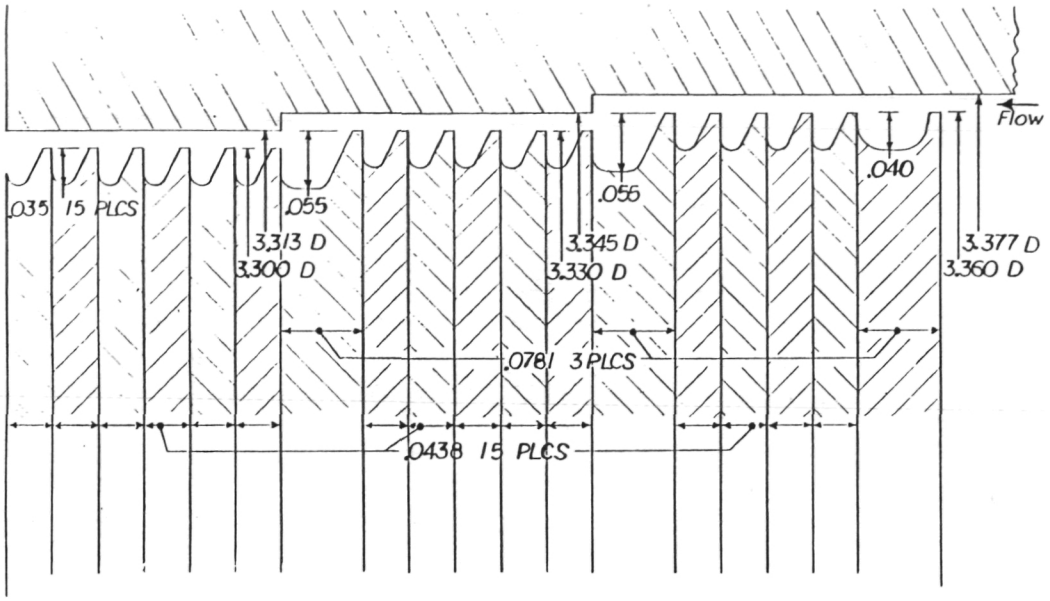


Figure 40. Schematic of Straight-Through Labyrinth Seal with Curved Cavity Contours.

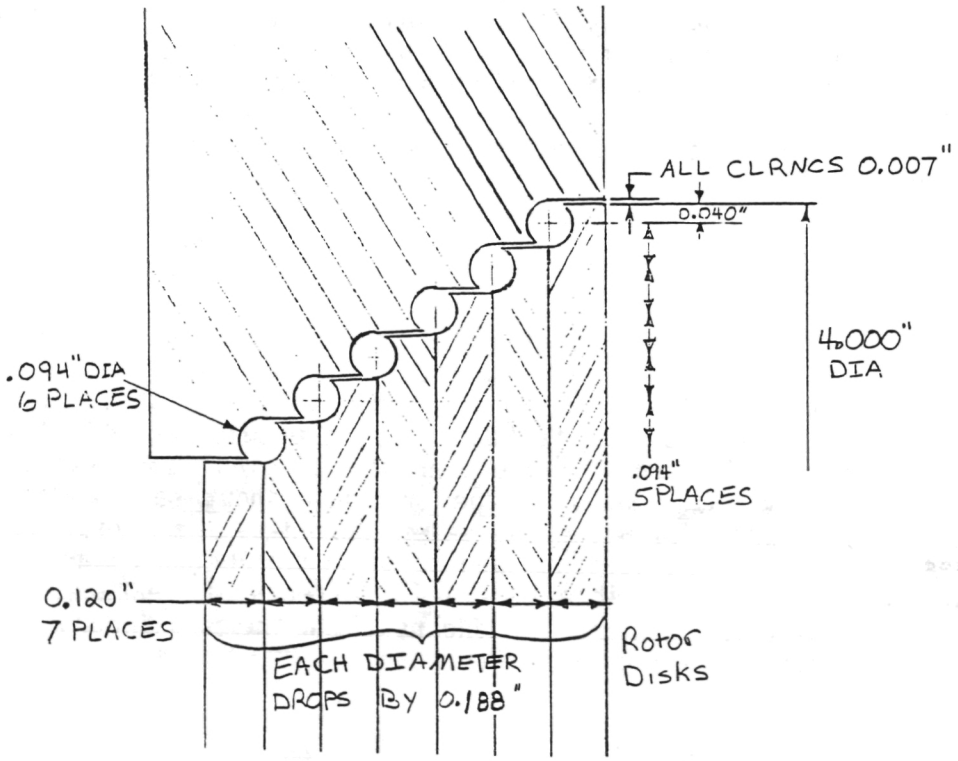


Figure 41. Schematic of the Stepped Labyrinth Seal with Circular Cavity Contour.

partial fulfillment of the requirement for the degree of Master of Science in Mechanical Engineering, December 1982.

Space Shuttle Main Engine (SSME) High Pressure Fuel Pump (HPFP) Interstage Seal

Reported in the 1982 R&T Annual Report was a test program conducted to provide an experimental basis for incorporating annular interstage seals in the SSME HPFP. As explained previously, the early HPFP model exhibited subsynchronous whirl and among the design changes incorporated in the pump to improve its stability were the annular interstage seals to provide added stiffness and damping. The seal design was based on theoretical calculations which were experimentally verified only by water tests at a relatively low Reynolds Number. The HPFP interstage seals, however, operate at much higher Reynolds Numbers. Reynolds Numbers as high as approximately 400,000 were achieved in the test program by use of Bromotrifluoromethane (FREON 13 B1) test fluid which is manufactured by Dupont as a fire extinguisher fluid and a refrigerant.

Significant findings and accomplishments resulting from this investigation thus far, are as follows:

a. The stiffness and damping coefficients determined for the stepped seal configuration were found to be approximately twice the predictions based on the previous stepped seal model.

b. The convergent-tapered smooth seal generated stiffness and damping coefficients approximately 2.0 and 2.5 times, respectively, those of the stepped seal. The leakage past the convergent-tapered smooth seal also increased by approximately 7 percent of that for the stepped seal. These finds definitely support the justification for incorporating the slightly tapered smooth interstage seal in the flight HPFP.

c. Surface roughness treatments reduce leakage but are more effective for the tapered seal.

d. In general, surface roughness treatments on either the rotating part or the stationary part of the seal reduced both stiffness and damping.

e. The added-mass coefficients were found to be relatively large for both the stepped and tapered seals.

An improved theory for prediction of the rotor dynamic coefficients of turbulent annular seals was developed from the previously developed models using the experimental data obtained from this investigation. The improved short seal solution provides better accuracy in predicting effective stiffness and damping coefficients than either the original short-seal model or the finite-length model. However, the original short-seal model provides better accuracy in predicting the equivalent added-mass coefficient.

Investigations are being continued to generate the necessary supporting test data to verify the possible beneficial effects in leakage and damping of a seal with a specific surface roughness on the stationary part while maintaining a smooth rotating part. (F. Garcia/EP23/205-453-3812)

Publication:

Childs, D. W.: "SSME HPFTP Interstage Seals: Analysis and Experiments for Leakage and Reaction-Force Coefficients," Progress Report, NASA Contract NAS8-33716, February 15, 1983.

Sponsoring Office: SSME Project Office at MSFC.

Pump Cavitation Damage

Cavitation bubble collapse can cause pitting of pump inducers, impellers and pump housings to the point that structural failure can occur. Evidence of cavitation damage has been observed in the Space Shuttle Main Engine high pressure oxidizer pump after limited operation. Cavitation damage is a time-dependent phenomenon; therefore, severe problems are expected when the engine life is extended to the design value if the damage cannot be eliminated or substantially reduced.

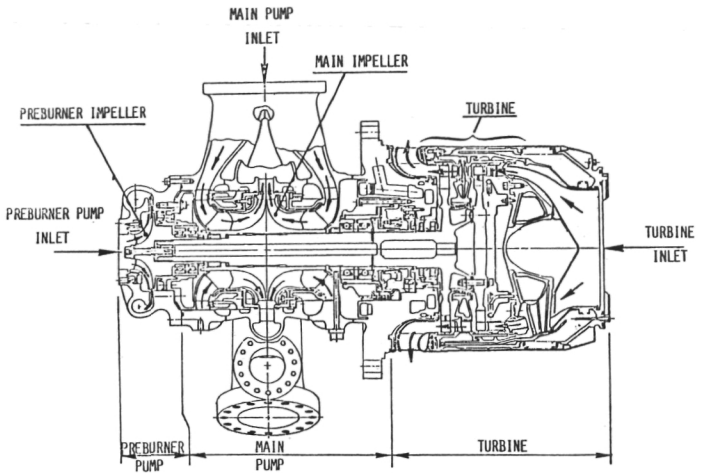


Figure 42. High Pressure Oxidizer Turbopump Flow Geometry.

The cavitation damage problem appears to be due to the unsteadiness of the flow into the inducer caused by the wakes of the vanes. In order to show this analytically, calculation procedures were developed that predict the flow through the inlet casing to the inducer inlet, the flow through the inducer and finally the pressure distribution on the inducer vanes. In addition, the boundary layer thickness was calculated on the vanes and with the application of a wake model, the velocity defect was estimated at the inlet to the inducer.

The flow field within the oxidizer pump is asymmetric and very complicated. New approaches to the flow analysis were developed to handle this problem. The most difficulty resulted from the asymmetry at the inlet casing. This component is responsible for varying the fluid pressure and velocity in the circumferential direction. Since the flow does not remain radial, but turns ninety degrees to become axial, the rotating blade components will see a three-dimensional variation in the fluid velocities.

The flow analysis is able to predict the fluid pressures and velocities at any given operating point. The pump components are analyzed one at a time in a marching fashion whereby the results of one component analysis are used as input to the next. The components considered in this fashion are (1) the inlet casing, (2) the stator ring, (3) the ninety degree bend, (4) the inducer and (5) the impeller. In all cases, a two-dimensional, inviscid

analysis is performed and pieced together to obtain any three-dimensional effect. Each component is examined individually, and viscous effects are added before analyzing the next component. This allowed the effects of boundary layers, wakes and secondary flows to be added to the potential flow solution to determine the actual flow into the next component.

The results of the initial analyses indicated that the wakes from several of the inlet guide vanes were of sufficient strength to generate unsteady flow in the inducer. The unsteady flow of the inducer vane tips creates the cavitation problem. Rocketdyne has performed air flow tests on the oxidizer pump inlet and has provided the results to the Pennsylavania State University for comparison with the analytical results. This comparison indicates that the theoretical model underpredicted the wake strength and overpredicted the circumferential variation in velocity. The analytical model has been corrected to account for more vane blockage. Pennsylvania State University had fabricated as a student project a two-dimensional model of the oxidizer pump inlet. Data obtained from air flow tests using the model support the Rocketdyne test results. The results obtained from this study have been incorporated in the Rocketdyne redesign of the high pressure oxidizer turbopump.

Work has begun on the preparation of the final report scheduled for distribution during November 1983. (G. Wilmer, Jr./EP23/205-453-1225)

Participating Companies/Sponsors: Applied Research Laboratory
Office of Aeronautics and Space Technology

Atomization and Mixing Study

Liquid Droplet Size Measurement

Rocket engine combustion analysis employs various computer models which have been developed based on combinations of both empirical data and theoretical relationships. The analytical approaches typically begin with assumptions of propellant conditions after injection into the combustion chamber. These assumptions are guided by an empirical data base containing droplet size distributions for various injector orifice patterns. The Marshall Space Flight Center is currently sponsoring work to update and expand the droplet size distribution data base to include injector patterns not adequately covered in previous work.

The measurement of droplet size distributions in an injector spray field remains a complex tedious task. In the current work, application of current technology principles of laser interferometry is being pursued to improve and accelerate this measuring process. To accomplish this a Helium-Neon laser beam is split (Figure 43) into two parallel beams and passed through appropriate optics to cross and form a region called the probe volume which contains alternating light and dark bands caused by the interference of the light wave fronts as the two beams cross. A droplet passing through the probe volume will reflect light as it passes through the light bands. A photomultiplier tube is focused upon the probe volume to detect the reflected light. Droplet size is inferred as a function of maximum and minimum voltage registered by the photomultiplier tube. Use of a microprocessor allows the processing of thousands of inputs per second giving the capability of data acquisition rates in the 5000 droplets per second range.

Scanning the spray field from an injector element can be done much more rapidly than by previous measurement methods. Since reflected light is used a much wider range of propellant simulants can be considered for use in the measurement tests including some instances actual propellants.

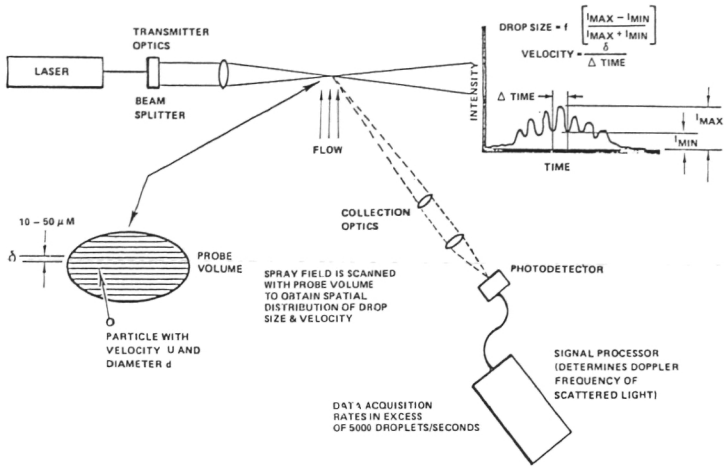


Figure 43. Laser Interferometry for Measurement of Droplet Sizes.

The laser interferometry measuring device is being developed by Spectron Development Laboratories in support of Rocketdyne, the Marshall Space Flight Center's contractor for this work. (F. Bramm/EP24/205-453-4827)

Publication:

Ferrenberg, A. J.: "Liquid Rocket Injector Atomization Research," presented at the ASTM Symposium on Liquid Particle Size Measurement Techniques, June 1983.

Sponsoring Office: Office of Aeronautics and Space Technology

PROCESSES

Melting Points of High Temperature Alloys Used in SSME

Many high temperature alloys are used in the SSME. A most important property of these alloys is the melting point (MP). The literature MP data have been obtained using many experimental techniques with a resulting wide dispersion of results. This task is directed towards experimentally determining the melting points of eighteen alloys under identically controlled conditions.

A high temperature differential thermal analyzer is used for experimental measurements. All data are recorded directly by computer which is used for data analysis of the cooling curves.

The preliminary results from the first eight alloys demonstrate the validity of this experimental technique. (J. Austin/EH32/205-453-1295)

Robotic Welding

Commercial robots have been used for welding since their introduction as spot welders for assembly lines. Gas metal arc welding has also become a common application for robots in simple, repetitive configurations. Until very recently, however, commercially available robots could not be used for the low volume high precision welds necessary for fabricating the Space Shuttle.

The advantage of using robots for welding on the Shuttle includes the consistent quality control possible in an automated weld as well as reduced tooling costs that results from the programmability of a manipulator for many different parts. NASA's Process Engineering Division at MSFC has assembled a robotic welding system using a Cincinnati Milacron T3-776 robot and Hobart Brother's welding power source. This system is being used to develop configurations and parameters for welding on the Shuttle's External Tank using the gas tungsten arc and variable polarity plasma arc welding processes. A block diagram of this welding is shown in Figure 22.

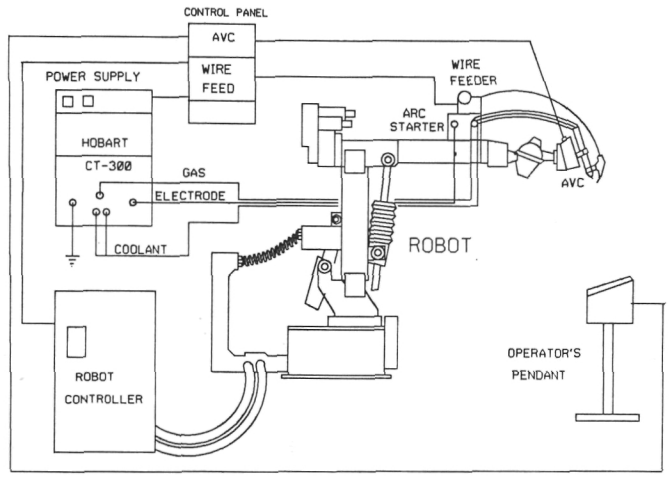


Figure 44. Robotic Welding System Diagram.

Research is also underway to develop sensors and control systems to supplement the intelligence of the robot's controller that will allow making even more precise welds. This type of weld is necessary for the fabrication of the Shuttle's Main Engines. The additional controls include a welding vision system for seam tracking and weld quality control and computer programs that will allow computer simulation of the robot's path to simplify programming the robot for different welds.

The general application of robots to welding on the Space Shuttle and the design constraints of sensor systems for control of welding on the Space Shuttle Main Engines are described in the following publications. (C. Jones/EH42/205-453-0012)

Publications:

Fernandez, K., Jones, C. S., and Roberts, M. L.: "NASA's Use of Robotics in Building the Space Shuttle," Conference Proceedings, 13th International

Symposium on Industrial Robotics and Robots 7, Vol. I, April 17, 1983, pp. 11-35 to 11-43.

Sias, Fred R., Jr.: "Sensor Control of Robot Arc Welding," a report under the NASA/ASEE Summer Faculty Research Fellowship Program by Dr. Sias of Clemson University School of Electrical and Computer Engineering, dated July 29, 1983.

Development of Automatic Meter/Mix/Dispense System for High Viscosity Polymeric Sealants

In the initial assembly of the SRB subsystem, component fasteners are installed wet with PR-1422 (polysulfide) sealant. The heads of all fasteners are covered with a plastic cap that is filled with PR-1422, resulting in an encapsulated fastener. This encapsulation protects the high strength fasteners from the salt water when the SRB's are being recovered after flight. During subsequent removal of the charred TPS (Thermal Protective Systems) from the spent SRB components, with high pressure waterblasting, the sealant and caps are removed and/or mangled beyond reuse. During the refurbishment of the SRB component, the sealant must be replaced prior to reapplication of protective paint and TPS.

An automated sealant application system has been developed that consists of a number of pieces of equipment, integrated for metering, mixing and dispensing the sealant in predetermined shot sizes for application to the exposed fastener heads. The major thrust of the development program was to reapply the sealant without the use of the plastic caps as initially assembled. The equipment consists of two positive displacement component feed pumps. The "A" (resin) and "B" (catalyst) components are then metered to a 7.5:1 ratio by another pump with variable displacement. The metering pump forces the two components through two separate high pressure hoses to a trimix valve which prevents crossover flow.

Downstream of the trimix valve is a mixer and a whip hose with a snuffer gun assembly with customized nozzles for a particular fastener head size and shape. The trimix valve allows all of the mixed "A" and "B" component material downstream to be flushed with solvent for equipment shutdown. The gun can be operated in several modes by changing a number of switches and digital micro-processor controls. The gun can be operated totally manually, manually with predetermined shot (timed) sizes, or automatically with predetermined shot sizes on a timed frequency. The system potentially offers the following advantages over the present methods:

a. Faster mixing with better mixed material homogeneity.
b. Better process efficiency to mix, apply and cleanup.
c. Elimination of need for plastic caps.
d. Simplified process relative to number of steps required.
e. Significant potential for follow-on automation using robotics, vision and tactile sensor systems and turntables.

Liquid Helium Management for Gravity Probe-B

The Gravity Probe-B (GP-B) spacecraft will require a large volume of liquid helium for cooling of experiment components and for providing thrust

for maintaining required altitude, roll rate and net drag-free conditions. The requirement that accelerations on a proof mass in the experimental package be kept at 10^{-10}g or less places requirements on control of the configuration and dynamics of the liquid helium. A technique for managing the liquid helium configuration using a baffle system has been proposed and analyzed. Verification of some aspects of this technique will be tested in low gravity flights on the NASA KC-135. (C. Schafer/ED42/205453-1886)

Publications:

Schafer, Charles: NASA TM-82521, entitled "Liquid Helium Management for Gravity Probe-B," December 1982.

Schafer, C. F. and Lowry, S. A.: "Mechanics of Liquid Helium in a Partially Filled Rotating Dewar in Low Gravity - with Application to Gravity Probe-B," NASA Technical Paper 2124, January 1983.

Leslie, Fred, Schafer, Charles and Gaus, Roger: "Classical Model of Liquid Helium Management for Gravity Probe-B," Space Helium Dewar Conference and Workshop, Huntsville, AL, August 24-26, 1983.

Aeronautical Hazard Avoidance

Several significant accomplishments have resulted for efforts of the MSFC Aeronautical Program (505-45-09) during FY-83. Some of these are:

a. Low-Level Flow - An analysis of data from the 150 meter tower (KSC, FL) was conducted relative to flow conditions hazardous to aircraft. A report, "Significant Events in Low-Level Flow Conditions Hazardous to Aircraft," NASA TM-8255, dated January 1983, by Margaret Alexander and Dennis Camp, documents the analysis.

b. Joint Airport Weather Studies - The analysis of data gathered during the summer of 1982 has continued with numerous presentations by the principal investigators as well as several publications. Some of these publications are listed below.

c. These successful workshops were conducted where NASA/MSFC's work on the aeronautical efforts were of prime concern.

d. B-57B Gust Gradient Program - During the past year, the B-57B gust gradient data from the previous year was analyzed. Gust difference distribution functions were determined. Cross-spectra were calculated. These calculated spectra were compared with a theoretical cross-spectral model developed this year at MSFC.

An animation depicting measured wind vectors and B-57B dynamic response to these winds was undertaken. A sample two seconds of data during B-57B penetration of a microburst front was used in the initial study. The final result of the effort is a computer-generated animation of 100 seconds of data including the microburst encounter.

A three-dimensional Monte Carlo Turbulence Simulation Model was developed so that small scale features can be added to the JAWS wind shear data sets. The JAWS data contains information for flight simulation only up to approximately 0.25 Hz, whereas the aerospace vehicle response range extends well beyond this value making the addition of turbulence mandatory. (W. Campbell/ED42/205-453-1886 and D. Camp/ED42/205-453-2087)

Publications:

Campbell, W. and Frost, W.: "NASA's B-57B Gust Gradient Program," presented at the NASA/MSFC FY-82 Atmospheric Processes Research Review, October 19-21, 1982.

Campbell, W.: "A Cursory Glance at Results from NASA's B-57B Gust Gradient Program," presented at the Sixth Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems, 1982.

Camp, D., Campbell, W., Frost, W., Murrow, H. and Painter, W.: NASA's B-57B Gust Gradient Program," presented at the AIAA 21st Aerospace Sciences Meeting, Reno, Nevada, January 1983, and accepted for publication in Journal of Aircraft.

Campbell, W., Camp, D. and Frost, W.: "An Analysis of Spanwise Gust Gradient Data," presented at the AMS/AIAA 9th Conference on Aerospace and Aeronautical Meterorology at Omaha, Nebraska, June 1983.

Frost, W., Camp, D. and Campbell, W.: "Spanwise Turbulence Modeling," presented at the AMS/AIAA 9th Conference on Aerospace and Aeronautical Meterorology at Omaha, Nebraska, June 1983.

Frost, W.: "Flight in Low-Level Wind Shear," NASA CR-3678, March 1983.

Dietenberger, M.: "Generalized Correlation of the Walter Frost Thermal Conductivity," Int. Journal Heat Mass Transfer, Vol. 26, No. 4, pp. 607-619, 1983.

Keller, J. and Haines, P.: "Detection of CAT Using a Diagnostic Richardson Number Tendency Formulation," Journal of Aircraft, Vol. 19, No. 11, pp. 904-908, Nov.-Dec. 1982.

Keller, J.: "CAT Detection and Forecasting Using Operational NMC Analysis Data," paper presented at 9th Conference on Aerospace and Aeronautical Meteorology of the AMS, Omaha, Nebraska, June 6-9, 1983.

Frost, W. and Huang, K.: "Test Results of Modified Electrical Charged Particle Generator for Application to Fog Dispersal," NASA CR-3674, February 1983.

Christian, H., Lillie, L., Saunders, C. and Hallett, J.: "Laboratory and Field Observations Related to Ice Particle and Aircraft Charging in Convective Storms," International Conference on Lightning and Static Electricity, June 1983.

Christian, H., Frost, R., Gillaspy, P., Goodman, S., Vaughan, O., Brook, M., Vonnegut, B. and Orville, R.: "Observations of Optical Lightning Emissions from Above Thunderstorms Using U-2 Aircraft," Bulletin American Meteorological Society, 64, February 1983.

"Airborne Measurement of Atmospheric Backscatter at 10.6 Micrometers," presented at Society of Photo-Optics Instrumentation Engineering Conference, April 1983.

Frost, W. and Camp, D. (editors): "Proceedings: Sixth Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems," NASA CP-2274, April 1983.

McCarthy, J.: "JAWS Program," paper presented at AIAA 21st Aerospace Sciences Meeting, Reno, Nevada, January 1983.

Wilson, J., McCarty, J. and Fujita, T.: "Application of Doppler Radar to Aviation Operations - JAWS Experiences," paper presented at AIAA 21st Aerospace Sciences Meeting, Reno, Nevada, January 1983.

"The JAWS Project Operations Summary 1982," NCAR Report, Boulder, Colorado, February 1983.

McCarthy, J.: "Joint Airport Weather Studies (JAWS) Project," proceedings: Sixth Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems, pp. 85-95, NASA CP-2274, April 1983.

Geophysical Fluid Flow Cell (GFFC)

As part of MSFC's global weather research the GFFC experiment planned for Spacelab 3 nears completion. The system was designed and built by Aerojet Electro Systems Corporation under contract from MSFC. The rotating concentric spheres which enclose a model atmosphere were fabricated and tested. They contain temperature-controlled heaters and coolers which produce a commanded temperature distribution on the spheres. Temperature gradients under the influence of a dielectric gravity field drive the flows, which are modified by rotation and spherical boundaries to model geophysical atmospheres. Fabrication of the instrument was completed at Aerojet and the Integration Readiness Review was held. The GFFC was then shipped to MSFC, where it successfully completed vibration tests. The Spacelab 3 flight crew were given a briefing on the science issues addressed by the experiment, as well as a system description and hands-on operation of the flight hardware.

Software for programming the instrument with the science team's experiment scenarios was completed. A preliminary set of scenarios was received from the PI (Dr. John Hart at the University of Colorado) but changes are expected pending results of ground tests with the GFFC. These scenarios were chosen based on a linear stability analysis of the GFFC configuration. The first set of results was obtained by analytical theory and by initial-value solution using a combined spectral and grid-point numerical method. The neutral or critical Rayleigh numbers for the onset of convection were obtained for zero rotation, modest rotation and the highest rotation rate attainable in the GFFC. The latter two problems are non-separable in the sphere and hence the computations were of necessity numerical. The three values of the critical Rayleigh number versus rotation rate are sufficient to define the neutral curve for the GFFC accurately enough to enable a useful scenario selection. To check the results, a full spectral model solution for the critical Rayleigh number was obtained. The results of the two separate calculations agreed within 10% at the highest rotation rate where the effects of the radial boundary in the GFFC (but not in the model) will be most pronounced. (F. Leslie/ED42/205-453-2047)

Gas-Dynamics Active Simulator (GAS)

A primary concern of most large aerospace propulsion systems involves gas-dynamics including the internal flow of fluids, as well as the externally induced environments of acoustics and overpressure and other plume aspects. Various environments are thus pursued through costly testing of flight hardware or other complex full-scale propulsion elements.

Possibly precluding these expensive and sometimes inflexible tests, which in many instances do not allow direct measurement of environments of concern, is the current numerical analysis capabilities that have just crossed into an affordable and practical realm. These new analytical techniques have become more practical in terms of meeting schedules and being made useable with micro-computer facilities. The CM1000, a new microcomputer numerical analysis system just on the market from Continuum, Inc. of Huntsville, AL, represents a system desk-top or work-station tool available for an engineer in his office to handle an analysis of the time evolution of inviscid gas flows to steady state, maintaining absolute conservation. Multi-specie, non-reacting gas mixtures may be analyzed using two-dimensional or axisymmetric modes. Analysis can produce a stable numerical analog of the governing equations of motion for the most complex systems that heretofore defied all but experimental investigation. This type of desk-top microcomputer system is now being used to address hot gas flows, high pressure transitions and a variety of problems relating to aerospace flight system design, checkout and verification. Upgrading of these systems is now being considered to include viscous effects and other factors leading to greater application and better definition of physical processes that interact with and are part of these complex flight systems.

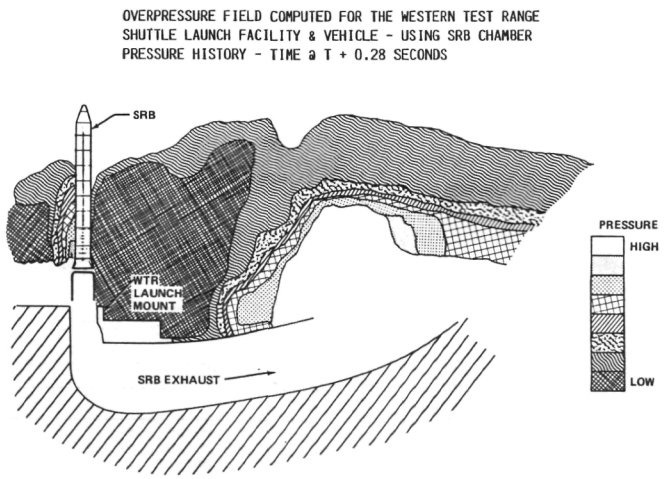


Figure 45. Typical Output-Gasdynamics Numerical Analysis Microcomputer.

The microcomputer application thus places a new powerful tool in the hand of the engineer or researcher who must otherwise seek long-term acquisition and costly experimental results to specifically satisfy very narrow problem areas and concerns. Use of these new numerical analysis

techniques will itself lead to their growth and broader adaptation to the whole of general gasdynamics problems.

Specific problems addressed by this system include the study of the over-pressure and related pressure waves emanating from the complex exhaust ducts of the SRB at the launch site at Vandenberg. This study showed the pressure wave interaction with the launch mount geometry, a general definition of the amplitudes involved, and therefore potential techniques to suppress the pressures, if needed, to acceptable levels. (S. Guest/ED23/ 205-453-1841)

Optically Beamed Energy Transfer Mechanisms

The optical transmission of energy in space by means of a high-power laser beam offers the potential of efficient conversion of that energy at some receiver into spacecraft electrical power or propulsive thrust. In the latter, one potential propulsion concept involves the heating of hydrogen propellant to very high temperatures (several thousand degrees kelvin) via high-temperature laser-sustained plasma. The heated hydrogen gas is then expanded through a nozzle to produce thrust. Typical specific impulse values are in the range of 1000-2000 seconds. The laser-heated hydrogen thruster is shown conceptually in Figure 46.

MSFC has undertaken an experimental research program to investigate the critical technology issues associated with this propulsion concept. The principal thrust of this program is an investigation of the properties of laser produced plasmas in hydrogen. These plasmas will be produced in the NASA High Energy Laser Propulsion (HELP) facility using a 50 CO_2 kW electric discharge laser. Laser operational readiness tests are being completed and laser action in excess of that required to perform the planned plasma experiments has been achieved.

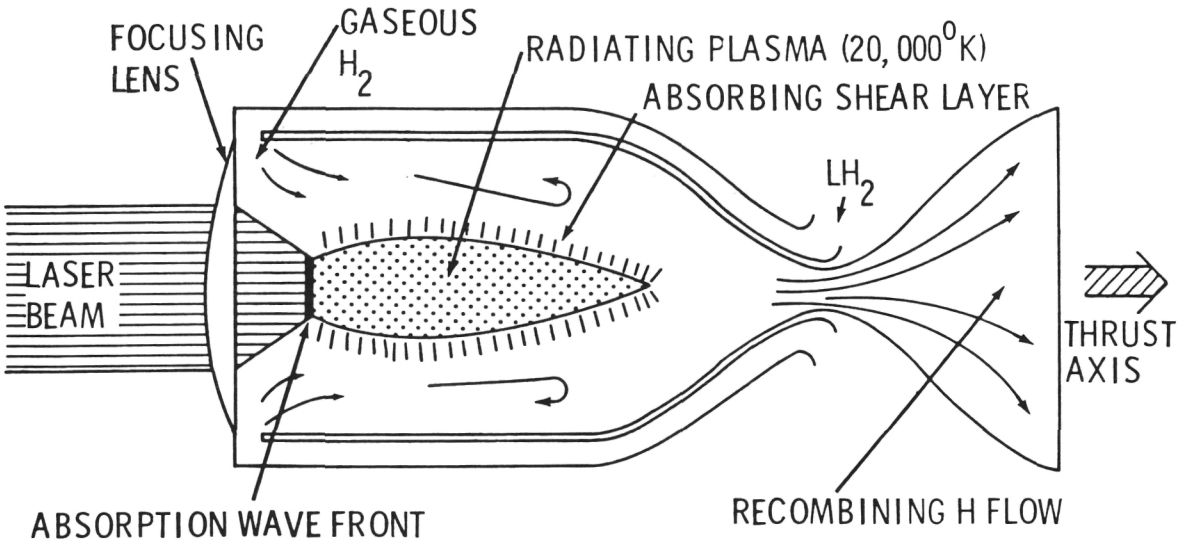


Figure 46. Laser-Heated Hydrogen Thruster.

A video data acquisition system has been developed which utilizes spectroscopic measurement techniques to determine the spatial distribution of temperatures in hydrogen plasmas. A plasma ignition scheme has been developed and studied using a pulsed CO_2 TEA laser and a high-speed streak camera. From the data acquired, the plasma ignition thresholds and wave front velocities were determined for several gases in addition to hydrogen.

In addition to the study of plasmas in pure hydrogen, a cooperative effort has begun to study molecular absorption processes in water-seeded hydrogen as an alternative to the absorption of laser energy by hydrogen plasmas. This work is co-funded by the Air Force Rocket Propulsion Laboratory (AFRPL). These experiments will involve measurement of properties in a propagating laser-supported thermal wave in H_2/H_2O mixtures. Diagnostic techniques to be used in these experiments will include acoustic temperature measurements and optical measurements of CO_2 laser absorptions. (Dr. T. McCay/EP23/205-453-3921 and L. Jones/ EP24/205-453-0709)

Publications:

Jones, L. W., Keefer, D. R., Elkins, R. and Peters, C.: "Laser Thermal Propulsion," Prog. in Astro. and Aero., October 1983.

McCay, T. D.: "Numerical Modeling of Laser Thermal Propulsion Flows," in Prog. in Astro. and Aero., October 1983.

Jones, L. W. and Keefer, D. R.: "NASA's Laser Propulsion Project," Astro. and Aero., September 1982.

DeYoung, R. J., Walberg, G. D., Conway, E. J. and Jones, L. W.: "A NASA High-Power Space-Based Laser Research and Applications Program," NASA SP-464, 1983.

SPACE STRUCTURES

LSS Ground Test Facility

The Ground Test Verification (GTV) experiment for this activity is shown in Figure 25. The first test article is an ASTROMAST with a few structural modifications. The ASTROMAST has a weight of about five pounds, is approximately 45 feet in length and is composed of S-glass. The structural modifications are to lower the ASTROMAST's fundamental frequency and to densely pack the modal vibrations. The test article and any ancillary equipment mounted to the test article are suspended by a constant tension cable connected to a tripod which is free to translate on air bearings.

The test article is mounted to the payload mounting plate of a modified Advanced Gimbal System (AGS) engineering model. The AGS modifications include the addition of a third gimbal and a sensor which provides closed-loop control capability for the third gimbal. The third gimbal facilitates rotation of the test article about its center line so that different test setups can be achieved.

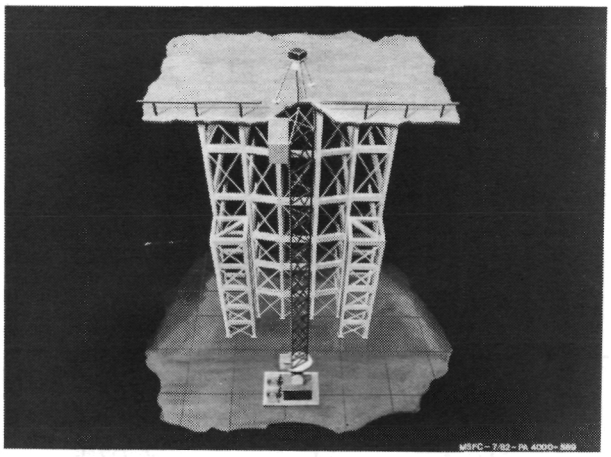


Figure 47. Pictorial of Ground Test Verification Experiment.

The AGS sits upon the base which is free to translate. Programmed disturbances to the base are effected by linear actuators and the disturbances are to include typical Orbiter attached inputs and a free flyer disturbance input.

Sensors are mounted to the AGS payload mounting plate and to the tip of the test article. Three Apollo Telescope Mount (ATM) rate gyros are located on the payload mounting plate and three Kearfott 2401 accelerometers are located at the AGS base. A Kearfott Attitude Reference System (KARS), along with three Kearfott 2401 accelerometers, are located at the tip of the test article.

The signals from these sensors are read by the control computer and processed according to the control algorithm under study. The control computer provides torque information to the AGS as inputs to the test article.

The control computer interfaces with a Hewlett Packard 9845C computer which stores data as collected from the test run. The data is transferred to either a disk or a tape for off-line data reduction. The sensor and effector data are recorded at each sample period and off-loaded to the storage device.

The LSS/GTV subsystems are currently in various stages of checkout and development at NASA/MSFC. Much of the functional data concerning the ground test system will be found in references and each subsystem will be thoroughly checked out and integrated where possible to other subsystem elements for functional and dynamics verification. This test procedure will be used to ferret out as many hardware and software problems as possible so that complete assembly checkout will be effected with great assurance. (H. Waites/ ED12/205-453-2310)

Publications:

Waites, H. B., Doane, G. B. and Tollison, D. K.: "Definition of Ground Test for Large Space Structure (LSS) Control Verification," AIAA Guidance and Control Conference, Gatlinburg, Tennessee, August 15-17, 1983.

Waites, H. B., Seltzer, S. M. and Doane, G. B.: "NASA-VCOSS Dynamic Test Facility," Ninth DARPA Strategic Space Symposium, Naval Postgraduate School, Monterey, California, October 4-7, 1983.

Automatic Rendezvous and Docking System

With the advent of the Orbital Maneuvering Vehicle, Space Station and related future space operations, improvements in rendezvous and docking technology become increasingly important. In recognition of this need, the objective of this work has been to develop techniques for automating the rendezvous and docking task. A video-based technique developed under contract with Martin Marietta, which uses a three-light target pattern configuration (subject of last year's report), was further evaluated in a digital simulation at MSFC. At Martin Marietta, Denver (contract NAS8-34679), this same technique was assessed in a physical simulation with actual hardware. Results of both of these studies testify positively in support of this technique. Another approach receiving attention during this past year is one based on using a polarized interferometer as the position and attitude sensor. The polarized interferometer is a radio frequency system requiring both spacecraft to be equipped with a multi-element antenna array. Through the combination of round trip signal timing and determination of signal angle of arrival and polarization, relative position and attitude may be derived. Results of a study done under contract NAS8-34960 by Green Mountain Radio Research Company have established feasibility of this technique for the static case and have revealed no fundamental problems. Refinements to the algorithm used for both the polarized interferometer technique and the video-based technique are topics being considered for follow-on studies to be conducted in FY-84. (J. Michael/ED15/205-453-4585)

Publications:

Martin Marietta Company Report MCR-83-584, entitled "Development of an Autonomous Video Rendezvous and Docking System," Final Report, June 1983.

Green Mountain Radio Research Company Report Number TBA, entitled "Polarized-Interferometer Feasibility Study," Final Report, October 1983.

Man/Machine Assembly Analysis

Man/machine assembly analysis (MMAA) is a method for economically mixing Large Space System (LSS) assembly techniques. Methods of LSS assembly can be viewed as a continuum beginning with manual execution and progressing through remote operations to totally automated execution. A cost algorithm provides the framework for performing the MMAA. Given any large space structure/system, the MMAA will assess the mission requirements, determine the costs for the various assembly options, define assembly requirements and constraints for those options, and finally define the most cost-efficient assembly technique or mixture of techniques for that structure/system.

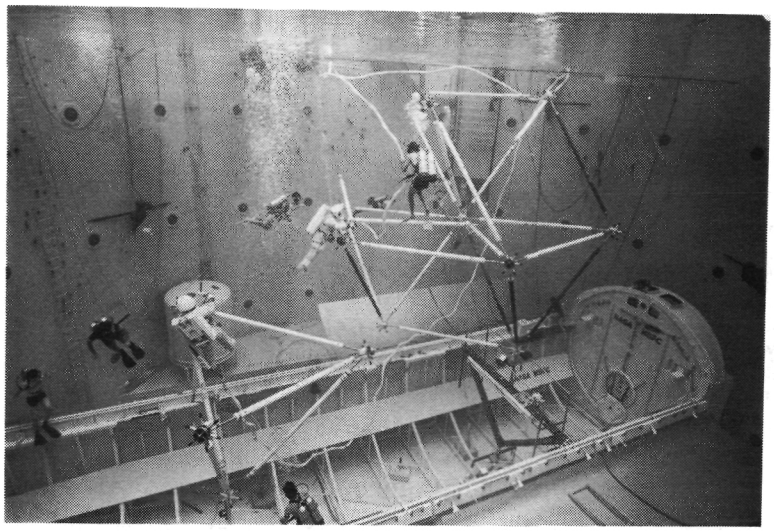


Figure 48. Man/Machine Assembly Analysis Methodology.

The analysis is functionally divided into two major sections, the data bases and the processes (Figure 26). The data bases include one each for manual, remote and automated assembly techniques, and cost element descriptions for the space transportation system. The process section is composed of four parts: one for preparation of the orbital system assembly scenario; one for the preparation of the functional analysis; one for the preparation of the task descriptions; and one for developing the MMAA itself.

Data have been collected for the data bases from various sources. Manual assembly techniques data have been the most easily obtainable, based upon flight (Skylab, SADE) and zero gravity simulations (neutral buoyancy, zero-g aircraft, etc.). Remote data and automated data have been based upon commercial ground-based remotely controlled equipment and robots, ground-based simulations (remote manipulator system, automated beam builder, automated orbital services, etc.) and paper analyses.

Also provided in the final report are an extensive LSS and robotics bibliography and design requirements identified from the various simulations. An output of the effort also was the design and development of an underwater functional mockup of the Shuttle manned maneuvering unit.

The MMAA was completed in August 1983, following a demonstration of its capabilities during an exercise for costing a Space Station concept. (J. Stokes/EL15/205-453-4430)

Subscale Diffuser for High Expansion Ratio Space Engine Testing

The purpose of this facility is to obtain engineering data to develop design criteria to be used to build a future full scale test facility for testing of OTV space engines in a simulated space environment. The design features the use of a commercial jet engine to provide the driving fluid for the injectors of the diffuser and is estimated to result in major cost savings over a conventional steam-driven system, as well as provide greater

flexibility in test operations. The capital outlay expenditure will be reduced by 80% and the operating costs by 90%. The major savings in operating costs are realizable because the input energy is applied and used directly at the ejector operating point as opposed to the conventional steam system where steam energy is accumulated and stored prior to use. The system will be capable of long duration and multiple tests during a given day. The facility will not require an extensive warm up period before use and is capable of demand usage.

The ejector design will feature the use of a large volume mass flow at a relatively low pressure of the ejector operating medium as opposed to the conventional low volume high pressure steam ejector driving medium. The mass flow is approximately three times the steam system and the ejector driving pressures are approximately one-third the steam system. The ejector area ratios are also lower as compared to the steam ejector system. The ejector design also features a multi-point operational capability through the use of variable area ejectors as opposed to the single point design of conventional fixed area ratio ejectors. This feature will enable the testing of a wide range of OTV space engines. (K. Riggs/EP23/205-453-0439)

Participating Companies/Offices: Lockheed Missiles and Space Company, Inc. Office of Aeronautics and Space Technology

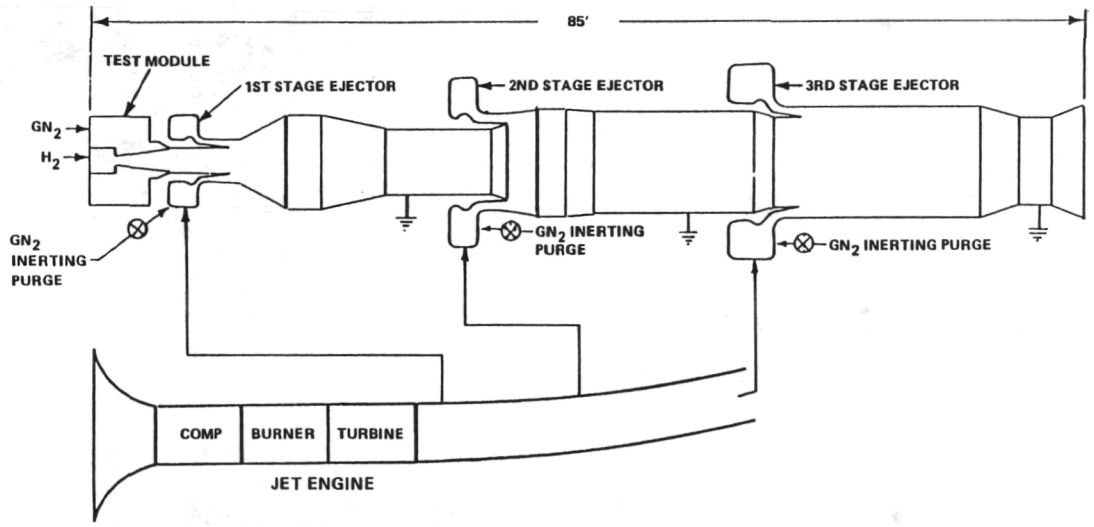


Figure 49. Jet Engine Driven Ejector/Diffuser System.

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16. ABSTRACT

The Marshall Space Flight Center conducts research programs in atmospheric science, materials processing in space, and space sciences as well as technology programs in space power, materials processes, and space structures. This Marshall Space Flight Center 1983 Annual Report on Research and Technology contains precises of the more significant scientific and technical results obtained during FY 1983.

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